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I. INTRODUCTION AND SUMMARY

There is a curious inconsistency in current theories of managerial behavior. On one hand we find theories, ranging from teleological [1] to normative, [2] which map the outcomes of alternative behaviors into a single measure and predict or prescribe that behavior which will maximize this measure. These theories focus closely on the manager's problem of choice and leave largely unexplained his part in the process of generating and evaluating the alternatives from which he chooses. [3]

On the other hand we have theories, strongly positive in character, which virtually reverse this emphasis. By focusing on those processes by which a manager and his organization generate alternatives these theories have accomplished impressive feats of description and prediction using very simple choice mechanisms. [4] To a considerable degree, however, these theories are as vague about the source and structure of these choice mechanisms as the other theories are about the source of alternatives.

1/ Henderson, J.M. and Quandt, R. E. Microeconomic Theory, McGraw Hill, New York, 1958.

2/ Savage, L. J. The Foundations of Statistics, John Wiley, New York, 1954.. Schlaifer, R. Probability and Statistics for Business Decisions, McGraw Hill, 1959.

3/ Simon, H. A. Theories of Decision Making in Economics and the Behavioral Sciences, American Economic Review, Vol. XLIX, June 1959, pp. 253-283.

4/ Cyert, R. M. and March, J. G. A Behavioral Theory of the Firm, Prentice Hall, Englewood Cliffs, 1963.

It has been shown that the form of the maximizing theories is such that no empirical evidence can settle the controversy about whether managers maximize or satisfice. [5] We suggest, therefore, that the energies devoted to arguing these differences might better be spent in improving our understanding of the phenomenon itself--by whatever method one views as most promising.

We have chosen to investigate one of the hypotheses which have been suggested for the choice mechanism in recent positive theories of managerial behavior. [6] This hypothesis asserts that independent goal values are maintained by managers on each decision variable in their environment-goal values which act both as triggers for initiating, and criteria for stopping problem solving activity.

We chose to investigate this hypothesis for three reasons. First, no empirical work has been done directly on this hypothesis and it appeared to offer an interesting subject for investigation. Second, as detailed empirical work proceeds from the relatively tranquil world of managers whose problems are modestly well defined (trust investment, assembly line balancing, etc.) to managers who must react in real time in a complex environment, we believe that the choice mechanism will become an increasingly important part of our theories of managerial

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5/ Clarkson, G. P. E. The Theory of Consumer Demand: A Critical Appraisal, Prentice Hall, Englewood Cliffs, 1963.

6/ Cyert, R. M. and March, J. G., op. cit. pp. 34 - 35.

behavior. And third, we believe that an understanding of the choice mechanism will both contribute understanding and suggest methods for dealing with the increasingly important problem of implementing the results of normative theories of management decision making.

As a result of experimental work with subjects in laboratory situations we are led to reject the hypothesis of the choice process which suggests that independent goal values are maintained on each decision variable. We have suggested instead that problem solving activity is continuously allocated to variables in the environment of the decision maker by relatively stable associative processes defined over the set of perceived variables. We have been able to describe some aspects of the choice behavior of fifteen subjects by means of an extremely simple associative structure. In a somewhat more complex situation we have been able to describe the behavior of three subjects using a slightly more elaborate associative structure.

While encouraged by the effectiveness of relatively simple and stable structures in explaining the choice behavior of some subjects, we found that the behavior of a number of other subjects could not be explained so easily. As a result we were led to hypothesize that in general the associative structure itself is modified by the subject as he interacts with his environment and that no single structure should be expected to describe behavior over time. For this reason we turned to an experimental procedure which permitted direct observation of the mechanism itself.

After giving subjects some experience in an experimental situation we asked each of them to describe a choice mechanism, i. e., a

rule to which he would be willing to delegate his decision making for the remainder of the experiment. In each case the rule which the subject prepared could be described by an associative structure which related data from his environment to problem solving operators which he had developed. As a result of this evidence we were led to accept the hypothesis that the choice mechanism can be presented by an evolving associative structure and suggest an investigation of the process of this evolution as a subject for future research.

II. BACKGROUND

In the early 1950's a rather sophisticated decision rule was developed for the problem of scheduling production and employment in factories facing fluctuating demands for their products. While the rule is quite generally applicable to such problems, it was developed in the context of a single manufacturing facility which contributed data on its operations for purposes of both guiding the development, and testing the general model from which the rule was derived. The rule was published in 1955. 7/

In return for their cooperation in the project, the developers of the rule presented the management of the company with the detailed results of their work with respect to the facility from which they had drawn their data. These results indicated that there were significant economic benefits to be gained from the new rule and the management of the facility agreed with these results. Soon after this presentation these same managers decided to use the rule for scheduling the facility on a trial basis.

After several months it was agreed among the managers that the rule should become the permanent basis for production and employment scheduling within this facility and plans were made to extend the application of the rule to other plants.

Three years later, it was observed that production and employ-

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7/ C.C. Holt, F. Modigliani, and H. A. Simon. "A Linear Decision Rule for Production and Employment Scheduling" Management Science, October, 1955.

ment decisions in this facility were not those recommended by the decision rule and there were strong indications that the recommendations of the rule had been ignored for some time.

Details of the events which followed the decision to use the rule and an attempt at a theoretical explanation of the later observation will be discussed in Chapter X, but to introduce the study which these events stimulated perhaps the problem should be placed in a more general framework.

Since the early 1940's there has been a growing theoretical interest in the problems faced by industrial managers. This interest has taken the form of an increasing allocation of resources by government agencies, academic institutions, and industrial organizations to the study of these problems. As a result of these efforts, a large and growing body of normative theory has been generated which appears to be of value to operating managers. The efficiency with which this body of theory is being transformed into effective managerial action is so low, however, that this process itself has acquired problem status. It is called the problem of implementation. [a/]

That implementation might be a problem is nowhere predicted in the body of normative theory. By assuming a profit maximizing criterion for the process of generating recommendations, and a profit maximizing objective for managers who might undertake to use them, these

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a/ R. A. Hammond "Making O.R. Effective for Management," Business Horizons, Spring, 1962, pp. 73-82.

developing this body of theory have effectively assumed away any problem of motivation with respect to implementation. In order to account for the discrepancy between these assumptions and observed behavior, an affective phenomenon called resistance to change [9] has been identified and discussed in connection with a number of attempts to implement normative theory.

The term resistance to change is one which has been applied to behavior observed in a variety of situations where a change agent attempts, under any one of a variety of arrangements, to modify the choice of behavior of a client system. In the human relations literature [10] this phenomenon is described in contexts varying from individual psychotherapy, through sociological processes of coping with community problems, to socioeconomic problems of changing work methods used by factory employees. Since the problem of implementation so clearly fits this framework, it is not surprising that it has been viewed primarily as one of affect and treated by the methods found to be effective in work on other instances of the resistance to change phenomenon.

In the theory which has evolved with respect to the change phenomenon, behavior is treated as a physical entity, subject to Lewinian forces and resistances, which exist in the environment.[11] The change agent's role is one of relaxing or unfreezing the resistive forces, exerting pressure on behavior in order to move (change) it to a preferred location, and then to re-establish the stabilizing environmental

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9/ L. Coch and J. R. P. French Jr. "Overcoming Resistance to Change," Human Relations, 1948, Vol. (1) 4, pp. 512-532.

10/ R. Lippett, J. Watson, B. Westley, The Dynamics of Planned Change, Harcourt Brace and Co. New York, 1958.

11/ K. Lewin, Field Theory in Social Science, D. Cartwright (ed.), New York Harper, 1951.

forces to insure that behavior will be held (frozen) in its new position.[12/]

A principal result of the work on the change phenomenon has been stated in the form of a participation hypothesis:[13/] "To bring about change in the behavior of the organization and to get effective acceptance of a new practice, it is necessary to secure the active participation in the decision of those whose behavior will be affected by the change." Tests of this hypothesis have yielded positive results under a variety of circumstances but the variables in these experiments are so gross as to offer little insight into either the phenomenon of resistance or into those essential elements of the participation process which yield the desirable effects.

For purposes of modifying community or group behavior this lack of precision does not appear to be too great a disadvantage--largely because of the difficulties involved in a more detailed control of such complex interactions. In the case of the implementation of a single decision rule, however, particularly in the highly structured environment of an industrial organization, a rather more detailed understanding of the phenomena of resistance and change would seem to be very valuable. The essential elements of the participation process might be simulated far more effectively than carried out if we knew what they were. An understanding of the process might suggest critical changes in the information and reward system of the decision maker which

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12/ K. Lewin "Frontiers in Group Dynamics," Human Relations 1947, 1, pp. 5-41.

13/ H. A. Simon, "Authority" Research in Industrial Human Relations, Arensberg et. al. (ed.) Harper and Brothers. 1957. pp. 103-118.

would greatly facilitate implementation. Such understanding might permit the modification of the decision process of an organization to occur by design rather than by incantation.

The same years which have seen the rapid development of normative theories of management have also seen a burst of theoretical interest in positive theories of individual and organizational decision making behavior. Studies of the processes involved in proving theorems in logic [14/] and geometry,[15/] playing chess [16/] and checkers,[17/] scheduling work on an assembly line,[18/] and allocating funds to securities in a trust fund [19/] have all been directed toward an understanding of individual problem solving process. Studies of price and quantity decisions in a department of a large retail store [20/] and of the managerial process of a large electrical manufacturing firm [21/] have been directed toward an understanding

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14/ A. Newell, J. C. Shaw, and H. A. Simon, "Empirical Explorations of the Logic Theory Machine," Proceedings of the Western Joint Computer Conference, (February 1957), pp. 218-230.

15/ H. L. Gelernter, J. R. Hansen, and D. W. Loveland, "Empirical Explorations of a Geometry Theorem Machine," Proceedings of the Western Joint Computer Conference (1960), pp. 143-149.

16/ A. Newell, J. C. Shaw, and H. A. Simon, "Chess-Playing Programs and the Problems of Complexity," IBM Journal of Research and Development (October, 1958) pp. 320-335.

17/ A. L. Samuel, "Some Studies in Machine Learning, Using the Game of Checkers," IBM Journal of Research and Development, Vol.3, No. 3, (July 1959), pp. 210-230.

18/ P. M. Tonge, A Heuristic Program for Assembly Line Balancing, Englewood Cliffs, New Jersey, Prentice-Hall, 1961.

19/ G. P. E. Clarkson, Portfolio Selection: A Simulation of Trust Investment, Englewood Cliffs, New Jersey, Prentice-Hall, 1962.

20/ R. M. Cyert and J. G. March, The Behavioral Theory of the Firm, Englewood Cliffs, New Jersey, Prentice-Hall, 1963, pp. 126-148.

21/ J. W. Forrester, "Industrial Dynamics Cambridge, Mass., M.I.T. Press 1961.

of the organizational problem solving process. Active research is continuing at both levels of inquiry.

One of the most general results which has emerged from this work to date is evidence that complex or ultimate objectives are factored into relatively independent subgoals by the individuals or organizations pursuing them. For example, in chess, players pursue subgoals like "control the center of the board" or "gain an advantage of piece position" during much of the game rather than their ultimate objective, "checkmate." There is evidence that industrial managers too, seek subgoals like increased sales volume, or reduced production cost rather than profit per se. These subgoals are then further factored into relatively elementary problems for which problem solving routines exist or can be easily developed.

Behavior based on this subgoal structure is in marked contrast to the process of managerial behavior implied by most normative theories. These theories place great emphasis on the values assigned to certain events in the environment of the decision maker and formal models of the interdependence of these values on some ultimate objective like profit are constructed.[22/] Behaviors are then sought and frequently found which will result in some extremal value of the objective and a subgoal structure is neither required nor recognized in this procedure.

If, however, a manager's choice of behavior is based on a subgoal structure, it means that the implementation of normative theory

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22/ C. W. Churchman, R. L. Ackoff, and E. L. Arnoff, Introduction to Operations Research, New York, John Wiley & Sons, Inc. 1957.

requires not one change on the part of a manager but two. It means he must not only change his behavior but also the process by which he selects his behavior. It will be suggested in the following pages that this latter change is the fundamental source of the problem of implementation and perhaps the key to its understanding and solution. In order to get at this mechanism, however, it will first be necessary to state, test, and perhaps modify the existing theories of the choice process.

Chapter III will be devoted to a clarification of the concept of a goal as it has been used in various theoretical structures. Chapter IV will review one hypothesis which has been advanced of the choice mechanism. Chapters, V through VIII will describe some experimental tests of this hypothesis and suggest new hypotheses with respect to the structure of this process. Chapter IX will summarize these results. In Chapter X we will attempt to apply these results to the case described in the beginning of this chapter and Chapter XI will suggest directions for future research on these phenomena. Thus over the coming pages we will proceed analytically to some very basic processes, develop a theory of these processes and then attempt to apply this theory to those questions which stimulated our inquiry.

III. TWO KINDS OF THEORIES

A principal difference between descriptive and normative theories of human behavior is in their use of the concept of a goal. This chapter will be devoted to a discussion of the issues involved in this difference and to a clarification of the use of this concept in these two kinds of theories.

When we attempt to understand or explain why a particular event takes place, we find that the question can be interpreted in two ways. The word *why* is ambiguous. It can be answered either in terms of the purposes served by the event or in terms of the prior conditions and processes which predetermined or caused the event. An explanation based on the first interpretation is called teleological while an explanation based on the second is sometimes described as mechanistic. 23/

Philosophers have found no logical basis for choice between the teleological and mechanistic modes of explanation. In the limit both modes lead to what appear to be unanswerable questions. If a baker bakes bread for the purpose of selling it, and if he sells it for the purpose of making money, and he wants money for the purpose of buying food, clearly this string of objectives can be extended easily to a question of ultimate purpose which is, at least currently, impossible to answer. It seems, therefore, that teleological explanations are bounded by our knowledge of ultimate purpose.

23/ For a more complete discussion of these terms see: Bertrand Russell, *A History of Western Philosophy*, Simon and Schuster, 1945, p. 68; and R. B. Braithwaite, *Scientific Explanation*, Cambridge University Press, 1953, Chapter 10.

On the other hand, if a baker bakes bread because he is a baker, and he is a baker because he chose to become one, and he chose to become one because his father was a baker, we find this string of explanations leading inexorably to a question of first cause which is also difficult to answer. Thus mechanistic explanations are bounded by our knowledge, not of ultimate purpose, but of orginal cause.

Despite the logical disadvantages of both modes of explanation, we find that most theory can be roughly categorized as either teleological or mechanistic. Newtonian mechanics where the motions of bodies are explained in terms of prior properties like mass, velocity, and the forces acting on them is clearly mechanistic, while economic theory which assumes decision behavior will accomplish the purpose of utility maximization is obviously teleological.

In some cases, theories in each mode have been devised to explain the same phenomenon. The path of a light ray through a lens system, for example, can be explained both mechanistically in terms of the refractive properties of the system and the characteristics of light, and teleologically in terms of the path which will minimize the time required for light to get from a given source to a given destination. Kepler devised a teleological theory of planetary motion which preceded Newton's mechanistic theory. Thus it appears possible, in principle at least, to discover dual theories, one mechanistic and one teleological, by which events can be explained. If this analysis is correct, an attempt to decide in general which mode of theory is appropriate to a given question is a fruitless one since, given sufficient

effort, theories in either or both modes could presumably be devised. A much more appropriate question perhaps is, given that no satisfactory theory exists, what kind of theory seems most appropriate to attempt to build? This question grants the possibility of useful theories in either mode and suggests the appropriate criterion should be one of efficiency. 24/

In the attempt to devise theories of human decision making, teleological theories are particularly appealing. By introspection most of us are aware that the decisions we make are strongly affected by the goals we seek. It seems appropriate therefore, to attempt to understand decision making in terms of such goals. The search for a general set of goals which will be useful in understanding the decision process has had limited success, however.

To illustrate the process of a search for predictive goals, consider the problem of devising a teleological theory which will predict the form of a body of water. Most observations indicate that a body of water seeks to minimize the distance from its center of gravity to the center of the earth and a theory based on water having this objective will frequently make correct predictions. Suppose, however, one were to half fill a bucket with water and whirl it suitably around his head. He would observe that water would stay in the bucket at the top of the arc even though the distance from its center of gravity to the center of the earth is not minimized. In this case, the theory fails. To

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24/ For a more complete discussion of some of the issues of these two modes of theory see: C. G. Hempel and P. Oppenheim, "The Logic of Explanation." Philosophy of Science, Vol. 15, 1948.

explain this event one might invent an ad hoc objective for water in whirling buckets or, if he thought of it, generalize the purpose attributed to water as one of minimizing its potential energy subject to constraints. The latter theory would explain both phenomena in terms of the same goal and would, as a result, be a more powerful one than the original, as long as the concepts of potential energy and the constraints were operationally measurable.

Teleological theories of decision making have encountered a analogous problems. While in situations of certainty people decide to choose the higher of two alternative amounts of money, in uncertain ones they frequently don't choose the maximum expected value. To explain this, the maximizing goal attributed to people in this situation has been modified in two ways. In one, another ad hoc goal of uncertainty avoidance is offered which is in the same spirit as an ad hoc theory of water in whirling buckets. In the other, the individual's goals are generalized to a measure called utility which is similar in kind to the generalization of potential energy in the water case. The chief disadvantage of utility as a predictive device is the difficulty, both theoretical and empirical, of operationally measuring it. [25/] The attempt to do so continues, however, with optimism a variable over individuals.

During the past several years there has emerged a growing interest in mechanistic theories of individual and organizational behavior. [26/]

25/ H. A. Simon, "Theories of Decision Making in Economics and Behavioral Sciences," American Economic Review, Vol. XLIX, June 1959, pp. 253-283; and G. P. E. Clarkson The Theory of Consumer Demand: A Critical Appraisal Prentice-Hall, 1963.

26/ A. Newell and H. A. Simon, "The Simulation of Human Thought," Current Trends in Psychological Theory, University of Pittsburgh Press, 1961, pp. 152-179.

R. M. Cyert and J. G. March, Behavioral Theory of the Firm, Prentice-Hall, 1963.

This interest appears to have arisen out of a feeling of dissatisfaction with progress and promise in the classical teleological theories of decision making and the availability of the first time of a methodology by which complex mechanistic theories can be tested.

While most mechanistic theories find the concept of purpose to be unnecessary, a substantial amount of evidence suggests that human behavior, and therefore human decision making, is goal oriented. In the attempt to describe this aspect of human behavior the concept of a goal has been found useful even within mechanistic theories of human and organizational decision making but its role in these theories is distinctly different from that which it plays in teleological theories.

In these (mechanistic) theories, behavior is viewed as a specific consequence of complex cognitive processes operating on information available to the decision maker either from his memory or from his environment. A description, therefore, of the available information and the process used, completely defines a theory which will predict specific sequences of behavior. This theory can be tested by comparing the predicted behavior to that exhibited by individuals or organizations under the specified conditions. Thus these theories are based entirely on certain physical processes of sensing and symbol manipulation and teleological assumptions are not required.

In the construction of these theories it has been observed, however, that the elementary cognitive processes appear to be organized in a hierarchical, branching structure where a principal or executive process selects among the alternative processes at each branch point in

the hierarchy by evaluating certain attributes of memory and of the environment. The particular values which become associated with these branch points in the theory can easily be interpreted as goals for the routines below [in the theory] them in the hierarchy. It should be emphasized that this interpretation, while suggestive of the role played by these parts of the theory, is in no way necessary to the theory. Neither does it follow that the processes associated with these values differ in any fundamental way from those specified in other parts of the theory. Thus while the term goal is frequently used in the literature describing work on mechanistic theories of decision making, its function in these theories is quite different from that which it serves in teleological theory.

To summarize, in teleological theory, behavior is a variable whose value depends on its consequences. In mechanistic theory behavior in a given environment determines its consequences. In teleological theory behavior is assumed to be such that it will accomplish a goal e. g., profit maximization. In mechanistic theory behavior is selected by a process operating on values derived from the environment or memory, some of which have been called goals with respect to other parts of the process. Thus teleological and mechanistic theories of behavior differ in several fundamental ways most of which depend on their differing interpretation of the concept of a goal.

When teleological theory, developed in the context of a goal like profit maximization, fails to describe behavior, it can and frequently has been converted into normative theory. Thus normative theories, too, differ from mechanistic theories of the decision process in their use

of the concept of a goal.

In normative theory behavioral recommendations are derived from their consequences in terms of some criterion in precisely the same way behavior was predicted under teleological theory. The difference in this case, however, is that the results are interpreted as prescriptive rather than evaluated as to their descriptive power.

In order to understand precisely what these prescriptions imply for the manager it will be necessary to examine more closely the process by which he chooses his behavior in the absence of these prescriptions. To do so we will next turn to a mechanistic theory of goals and their modification through experience.

IV. A THEORY OF THE PROBLEM SOLVING CONTROL PROCESS

Most observations indicate that the intensity of problem solving activity exhibited by individuals and organizations varies over time. To explain this phenomenon problem solving control processes vaguely related to those reported in the psychological literature in connection with studies of the level of aspiration phenomenon have been hypothesized.[27] Very little empirical work has been done with respect to these hypotheses.

Before examining these hypotheses it may be worthwhile to examine those aspects of the behavior which they attempt to explain. Intensity or rate of problem solving activity is a difficult variable to measure. Since most evidence indicates that these processes may involve both internal and external searches for information as well as internal and external processing of this information, even careful observation of a decision maker may be a poor measure of the rate of problem solving activity. Thus it might be more appropriate to conclude that the rate of observable problem solving activity varies over time.

In addition, an observer might confuse the intensity of problem solving activity with the importance of the problem being worked on. Thus one might observe that a morning spent tidying up files and routine correspondence represents a lower rate of problem solving activity than a morning spent designing a million dollar sales campaign even though the level of cognitive activity might be very similar in each case. In

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27/ J. G. March and H. A. Simon, Organizations, John Wiley and Sons, New York, 1959, pp. 48-52.

other words variations in rate of problem solving may be measured with respect to what the observer thinks of as problems whereas it may be virtually constant from the point of view of the observed organism.

Notwithstanding the difficulty of measuring the aggregate rate of problem solving activity, we can certainly agree that the rate of problem solving activity with respect to individual variables in the environment of individuals and organizations does vary over time. We are all aware that we work on a relatively small set of problem variables during any short time interval and virtually ignore a variety of others. Since the hypotheses which have been advanced with respect to problem solving control processes will deal with this phenomenon as well as the aggregate one perhaps it is appropriate to consider them in this context.

We observe that a manager each week reads a report on the percentage of defective product being produced by a manufacturing process. For some period of time no problem solving activity is directed to reducing this percentage. Then a quality problem is defined with respect to this product and the manager and perhaps others in his organization direct their problem solving abilities to this problem. After some effort has been expended the project is closed and their problem solving energy is shifted elsewhere. The percentage of defective product being produced by the manufacturing process may or may not have been changed as a result of the project.

The behavior to be explained by the problem solving control or choice process is that of shifting the focus attention to this particular variable and the shifting of attention away from it. Thus the choice mechanism must explain the starting and stopping of problem

solving activity which itself can be explained by other theories.

A hypothesis, which has been advanced to explain the starting and stopping of problem solving, suggests that measures in the environment (like percent defective) are compared to a standard or goal value in the mind of the decision maker.[28/] If the measure exceeds the goal, that variable is in a satisfactory state and no problem solving will be all allocated to it. If on the other hand the measure fails to satisfy the goal, the variable associated with that measure is in an unsatisfactory state and constitutes therefore a problem which demands problem solving activity.

This hypothesis suggests a mechanism which is clearly capable of explaining the phenomenon. Without some testable theory of the process by which the value of the goal is defined, however, the hypothesis comes very close to being tautological. If problem solving activity or lack of it constitutes the only evidence of a goal level, then the concept of the goal level can not be used to predict problem solving activity.

To make this hypothesis meaningful, therefore, it is necessary to devise a theory of the process by which goal values are established and modified over time. To date no such theory has been proposed but some specifications of the characteristics of this theory have been suggested. These suggestions are based in large part on evidence reported in the psychological literature on what is called the level of aspiration phenomenon.

28/ Cyert, R. M. and March, J. G., op. cit.

In 1930, Hoppe suggested a new procedure for obtaining a behavioral measure of personality.[29] His procedure was carried out by Dembo in 1931 and his measure was given the name level of aspiration.[30] This name was strongly suggested by the experimental procedure: A subject in a laboratory situation is asked to perform a sequence of similar tasks where his performance can be measured along a single performance scale, e.g., time, distance, number of errors, etc. After completing each task the subject is given a measure of his performance (score) and asked to state the level of performance he proposes to accomplish on the next task. The score to which he aspires on the next task is defined as his level of aspiration for that task. Dembo and all writers since have defined level of aspiration as "the level of performance in a familiar task which an individual explicitly undertakes to reach."

Despite the fact that this definition is virtually identical to that which is implied by the word goal in the hypothesis suggested above for the choice process, and despite the fact that extensive research into the phenomenon is reported in the literature, this literature is not directly useful to one interested in the process of goal modification. Since those who have studied level of aspiration have been primarily concerned with the problem of defining a measure of personality, they transformed the results of their experiments on each subject into a single

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29/ F. Hoppe, "Erfolg und Misserfolg," Psychologische Forschung, 1930, Vol. 14, pp. 1-62.

30/ T. Dembo, 1931, "Der Ärger als Dynamisches Problems," Psychologische Forschung 15, pp. 1-144.

statistic which aggregated the task-to-task behavior. 31/ This statistic has been studied across tasks and subjects and its consistency with other personality measures and under various influences has been noted. Unfortunately the task-to-task data on performance and aspiration level is entirely missing in the literature.

Recently several attempts have been made to use the aspiration level idea to bridge the gap which exists between utility theory and behavioral evidence. But it is not at all clear that this attempt to bolster utility theory with a modicum of behavioral evidence will greatly improve the predictive power of either mechanistic or teleological theories of human decision making. 32/

One attempt has been made to suggest a theory of the process of goal modification 33/ but neither an operational means of measuring the variables suggested to be relevant nor evidence that a subject actually performs these evaluations has been offered. Several authors report almost in passing that aspiration levels tend to rise on success and fall

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31/ The particular statistic used was the following:

$$D = \sum_{n=1}^{N} (a_{n+1} - p_n)/N$$

where D = average difference score
N = total number of trials
n = trial number
a_{n+1} = aspiration level for trial n+1
p_n = performance level for trial n.

32/ For a review of these attempts see W. H. Starbuck, "Level of Aspiration" Psychological Review Vol. 70 No. 1, January 1963, pp. 51-60. This topic is discussed further in Chapter XI.

33/ K. Lewin, T. Dembo, L. Festinger, and P. Sears "Level of Aspiration" in Personality and Behavior Disorders, (ed.) J. M. Hunt, Ronald, New York, 1944 Vol. 1.

on failure. [34] These observations appear to constitute the state of our empirical knowledge of goal modification.

Despite the fact that an allusion to the level of aspiration phenomenon hardly constitutes a theory and despite the fact that virtually no theory exists of the process by which a variable like the level of aspiration might be generated, the concept of a problem solving control or choice mechanism is so necessary to mechanistic theories of behavior that theorists have been willing tentatively to accept the existence of such a process and to discuss some of its properties. Perhaps the most complete discussion currently available of these properties is one by Cyert and March in their recent book titled A Behavioral Theory of the Firm. [35]

After accepting a quantitative goal value as the mechanism which will control problem solving (or to use their term, search activity) Cyert and March describe some aspects of the process by which this value will change with experience:

1. In the steady state, aspiration level exceeds achievement by a small amount.
2. Where achievement increases at an increasing rate the level of aspiration will exhibit short run lags behind achievement.
3. Where achievement decreases, aspiration level will be above achievement.

34/ Frank, J. D. "Recent Studies of Level of Aspiration," Psychological Bulletin, 1941, pp. 218-225.

35/ Cyert, R. M. and March, J. G. A Behavioral Theory of the Firm, Prentice Hall, Englewood Cliffs, 1963, pp. 34-36.

They point out that these propositions are derived from simpler assumptions about the process which generates the aspiration level. These consist principally of the assumption that current aspiration is the result of an optomistic extrapolation of past achievement and past aspiration.

The authors go on to suggest that a model which would completely explain the process of goal modification might not completely describe the problem solving control process. In addition to this process they see the need for an attention focusing process which will permit the decision maker to attend at any one time to a sub-set of the set of variables in his environment. They suggest that it is the interaction of this focusing mechanism and the goal modifying mechanism which will constitute the problem solving control process which they see as required. Throughout this discussion the authors emphasize the lack of empirical evidence with respect to the phenomenon and the tentative nature of their description.

Because these mechanisms appear to be of fundamental theoretical importance and because these same mechanisms should be operating in the context of the implementation situation, it was decided that an empirical investigation of them should be conducted. In the next chapter we will discuss the design of an experimental situation designed to permit exploration of these processes.

V. DESIGN OF EXPERIMENTAL SITUATION I

In view of the lack of empirical evidence on the structure of the choice mechanism an attempt was made to design an experimental situation which would yield such evidence. In the process of design it was necessary, however, to consider current theories of behavior outside this area in order that the effects of these processes might be controlled. In describing the experiment, therefore, it seems appropriate to review briefly the structure of the overall process which was hypothesized prior to the design.

If we assume that the human organism is capable of receiving only a small sample of the total information available from the environment, and further that it is capable of processing (attending to) only a small fraction of the information which it can receive, and that this processed information is the basis for decision making, then to understand decision making we need a theory of how the limited information processing capacity is allocated to the received information and how the limited receiving capacity is allocated to the available information. The hypothesis used for design purposes was that two coding processes could provide at least the framework for such a theory.

The first coding process is that of categorization. This is a process whereby the decision maker codes the raw data he receives into what might be called variable classes. For example an executive in a firm attends to a set of reports on such classes of variables as share of market, labor cost per unit, work force size, forecast demand, etc. These variable classes contain far less information than is available in his

environment and as such his system of categories constitutes a filter by which he controls the information he receives. Other examples can be constructed which suggest that the categorization process is a general filtering method not confined to executives or managerial behavior.

The process by which categories are constructed is described in the psychological literature under the general title of concept formation and has for the most part been studied in the context of laboratory situations where other parts of the decision process were largely suppressed. 36/ This process has also received attention under the general name, pattern recognition, and reports of work on this process have emerged from an interesting variety of theoretical disciplines. 37/ It seems clear that the theories of this process whether under the name concept formation or pattern recognition will fit into a general theory of decision making as the first of the two coding processes being described here.

If we assume that information from the environment is coded into a set of measures on a well defined (but not necessarily constant) set of variable classes, the next problem facing the decision maker is to allocate his limited processing abilities over this set of variables. It has been suggested that this allocation is accomplished by the second

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36/ For a description of this work see: Bruner, Goodnow, and Austin, A Study of Thinking, Wiley, 1956.

37/ H. D. Block, "The Perceptron: A Model for Brain Functioning I," Reviews of Modern Physics, Vol. 34, No. 1, January 1962, pp. 123-142.

M. Minisky, "Steps Toward Artificial Intelligence," Proceedings of the IRE, Computer Issue, Vol. 49, No. 1, January 1961, pp. 8-30.

coding process. This process is one which codes variable classes into two categories by means of values called goals.

Measures on variable classes are constantly received from the environment, e. g., workforce size - 100 men, estimated share of market - 62%, etc. These measures are compared with goal values on the appropriate variable class and, at least as a first approximation, a simple categorization results. If a measure exceeds its goal value (where exceed is defined within the definition of the variable class) this variable class is a member of the set of variable classes which requires no further information processing. If, on the other hand, a goal exceeds the measure received, this variable class is a member of the set of variable classes which constitutes problems, and requires information processing of the problem solving type, i. e., find a behavior routine to reduce the difference between the measure and the goal. [38] The execution of the routine discovered by this processing constitutes observable behavior.

The existence of goals on each class of variables does not guarantee, however, that the information processing called for will bear any particular resemblance to the information processing capacity of the decision maker. A particular setting of goal values could overload or leave idle the problem solving mechanism. These two possibilities can be considered separately.

Assume for the moment that goal settings are such that demands for information processing exceed the decision maker's capacity to do this

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[38] A. Newell and H. A. Simon, "A General Problem Solving Program for a Computer," Computers and Automation, Vol. 8, July 1960, pp. 10-17.

work. Two mechanisms for solving this type of allocation problem exist. The first is to ignore one or more variable classes and thereby remain ignorant of the fact that capacity is exceeded. The second is to modify goals downward in such a way as to bring the number of problems within the capacity of the processing system. It is suggested that both methods of resolving this problem may be used.

Assuming conversely that the information processing capacity is not being fully utilized at a given goal setting, two alternatives are also open to the decision maker. He can either enlarge the number of variables to which he will attend or he can raise goals on the existing classes. Here, too, it is suggested that both mechanisms may be used.

While the four mechanisms just described would produce an allocation of processing capability, these descriptions offer no insight into the process by which those mechanisms accomplish this allocation. It is, therefore, to the problem of goal modification and the problem of controlling the set of variable classes to which we will now turn.

Assuming as a first approximation that the information receiving and processing system is sequential, a single sequential process must be capable of performing the work of the four mechanisms just described. 39/

While it is probably true that the categorization process described earlier is carried on in conjunction with the modification of goals and variable sets, it will be assumed for simplicity that the total set of variables classes is given and will remain fixed. The following theory

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38/ For a general discussion of these mechanisms and their implications for behavior see: March and Simon, Organizations, Wiley, 1959.

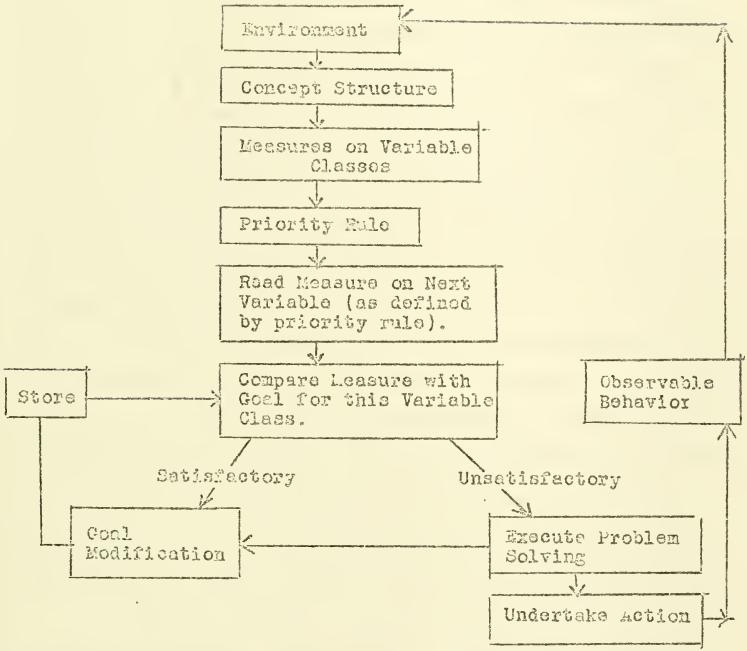
Environment
Concept Structure
Measures on Variable Classes
Priority Rule
Read Measure on Next Variable (as defined by priority rule).
Store
Compare Measure with Goal for this Variable Class.
Observable Behavior
Satisfactory
Unsatisfactory
Goal Modification
Execute Problem Solving
Undertake Action

FIGURE 1.

If, for example, a measure, which is satisfactory under the existing goal, results in the goal being sharply raised before it is stored, it is quite likely that over time this variable will become unsatisfactory and thus constitute a problem in the future. Similarly, if the goal associated with a variable class which is currently a problem is sharply lowered when corrective action is undertaken, this action will almost surely be successful. Thus the goal modification scheme interacts with the priority process and the environment in controlling the set of variables to which the decision maker will attend and the amount of problem solving activity he will undertake.

To summarize, three processes have been described which when acting together will control the information the decision maker receives and allocate his limited problem solving ability to a limited number of problem variables. The first of these processes is that of categorization. The second is a priority assignment process, and the third is a goal modification process. The existence of these three processes is the hypothesis which guided the design of the first experimental situation.

Since the subject of interest is the goal modification process every attempt was made in the design of the experimental procedure to control for the effect of the other two processes. Following a description of the procedure which was used, some of the considerations which led to it will be discussed.

After reading a detailed set of instructions, [40/] a subject was asked to indicate the performance he hoped to achieve on the first of a series of trials. In his instructions he was informed that the performance measures, and therefore the goal value which he was to indicate, were

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40/. Appendix A

expressed in units of dollars and cents. He wrote his first goal value on a blank opposite trial number one on a form provided for the purpose. The experimenter then compared the subject's goal value for trial number one with a previously prepared list of performance measures. If the goal value exceeded the performance value the subject was told that he "lost" on the first trial. If the performance value exceeded the goal value the subject was told that he had "won" on the first trial. If the subject won, he was asked to circle the goal value on the form and write a number one beside the circled value. He then proceeded in either case to indicate his goal for trial number two, and the process continued.

The instructions indicated considerably more about the situation than this basic procedure, however. They indicated that the subject should imagine himself winning the amount of his goal value on all those trials where he won. The instructions also indicated that there is a charge levied on every trial whether it was a win or a loss. Thus at the end of the experiment the subject could add all circled goal values, i.e., wins, and subtract the fee per trial times the total number of trials to determine his net earnings for the experiment.

The length of the experiment in terms of number of trials was not specified. The trials continued until the subject "won" fifty times. This could be accomplished in a minimum of fifty trials if no losses occurred. No limit on the total number of trials was imposed.

With respect to the performance data, the instructions indicated that they had been predetermined by choosing values from a carefully selected set of values, with replacement, by a random process. Thus the subject knew that his performance data were drawn randomly from

a stable probability distribution. He was given no indication, however, about the form or the parameters of this distribution.

Unknown to the subject the cost per trial and the parameters of the performance data distribution were selected to make the game quite benign, i.e., a wide range of goal values would yield positive net earnings over the course of the experiment. Within this constraint a variety of trial costs and parameters were used in the experiment to reveal the effect, if any, of such changes on the goal modification process.

Figure 2 indicates the relationship believed to exist between this experimental procedure and the theory discussed on pages 26-32 and represented in Figure 1. Figure 1 is reproduced in Figure 2, over the title "Theory" for convenience. The other diagram in Figure 2 represents the same process as it would apply to the experiment.

A concept structure was provided by the instructions and the priority rule was trivial since only one variable class was relevant to performance. Problem solving was trivial since the performance data is known to be predetermined. Thus the goal modification routine is the only part of the process which the subject had to consider. The experiment thus was designed to provide data on this process and only this process in an otherwise very structured situation.

Several choices made in the design of the experimental situation deserve comment. The feedback of simple win - lose information on performance was one of several alternatives considered. It was selected principally because of the difficulty in so simple a situation to stimulate the effect of goal value on performance. It is conjectured that these two variables are not independent. The choice of the win - lose measure

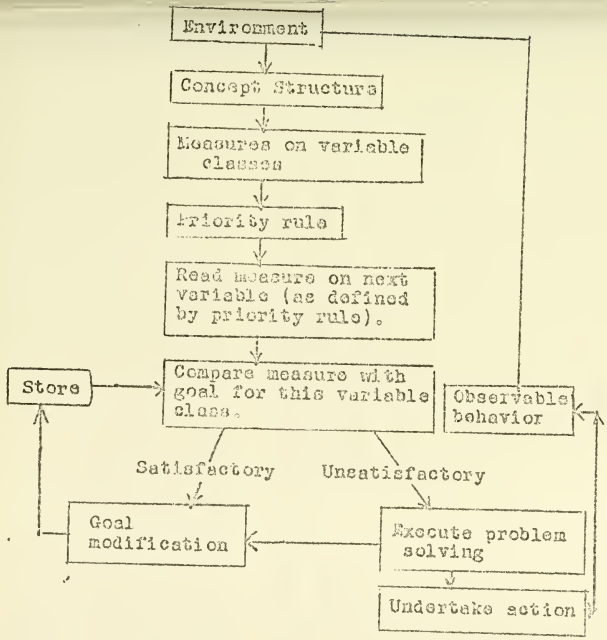
Environment
Concept Structure
Measures on variable classes
Priority rule
Read measure on next variable (as defined by priority rule).
Store
Compare measure with goal for this variable class.
Observable behavior
Satisfactory
Unsatisfactory
Goal modification
Execute problem solving
Undertake action
THEORY
Experimental situation
Defined in instructions
Defined in instructions
Single variable therefore priority trivial
None
None
Subject enters value on form.
Performed by experimenter
Indicated by experimenter
Indicated by experimenter
Performed by subject
None possible
EXPERIMENT

Figure 2.

assumes they are highly dependent. It assumes, in fact, that performance is limited to the goal value on success and limited to a fixed increment below the goal value on failure. The size of this fixed increment is set by the cost per trial. Since the experiment continues until the subject wins a fixed number of times, there are no "opportunity" costs associated with a loss.

The fixed cost per trial was included in the design of the experiment to simulate opportunity costs. In a more complex situation the subject would be forced to accept opportunity costs with respect to other variable classes each time he allocated his attention to a particular variable class. One would expect for example, that with great demands for problem solving capacity, goals on individual variable classes might tend to be lowered to reduce the demand. The cost per trial permits explicit variation of this effect.

The criterion chosen for the length of the experiment was related to the cost per trial considerations. If the experimnt had been defined to last a fixed number of trials, the total trial cost would have been fixed and the effect of this parameter of the situation would have been lost. By allowing the experiment to last for a fixed number of "wins" total trials becomes a variable and the "pressure" of other variable classes on the goal value for the experimental variable became real.

The decision to study essentially benign situations was based on the assumption that most of us require these for our survival. It was felt, therefore, that the subjects' processes for goal modification might be more adapted to these situations than to ones where ruin is

imminent. It was also based on the belief that the effect of a ruin barrier on behavior might most usefully be studied as a departure from behavior in a benign situation than as an independent process.

Based on current theories of the decision making process this experimental situation seemed a useful one for generating a rich set of data on the goal modification process. The results gained from running a number of subjects in this situation led to a second experiment and subsequently to a revision in the theory but first we turn to the results produced by the first experiment.

I. ANALYSIS OF BEHAVIOR IN EXPERIMENTAL SITUATION I

Experimental situation I, described in the last chapter, was designed to yield data on the goal modification process under carefully controlled conditions suggested by current hypotheses of the decision process. Subjects were run in the experiment not to test these hypotheses but rather to yield data which could be used to generate a theory of the process of goal modification. Analysis of this data, however, indicated that another hypothesis of the decision process was possible and potentially fruitful. This observation in turn led to the design of a second experimental situation in which the new hypothesis might be tested. In order to describe the development of this revised hypothesis, however, we will first review the results obtained in the first experiment.

Thirty two subjects participated in variations of the basic experiment. These subjects were drawn from among the graduate students and the faculty of the School of Industrial Management at Massachusetts Institute of Technology, and as such they probably do not represent a random sample of the population of the United States. Since their behavior was to be used to generate a theory of the goal modification process rather than to test alternative extant theories, this characteristic of the sample subjects did not appear to be a great disadvantage. The average subject took somewhat over 100 trials to complete the experiment and as a result the series of experiments yielded approximately 4,000 observations of the goal modification process.

These observations consisted of data sheets on which were recorded the individual goal values and their success or failure (win - lose)

for each trial plus the recorded protocol of each subject. Examples of the data sheets are shown in Appendix B.

The data for each experiment were plotted (Goal Value vs. Trial Number) as shown in Figure 3 to facilitate analysis. These plots indicated rather large individual differences in the goal modifications process. Nevertheless some general observations on this behavior could be made.

These data strongly supported the observations reported in the level of aspiration literature that goal values rise with success (win) and fall with failure (lose). Considering all subjects as a single sample the conditional probability of a win on the previous trial given that an increase in goal value was made from that trial ($P(W/\uparrow)$) was .87. The conditional probability of a loss on the previous trial given that a decrease in goal value was made from the previous trial $P(L/\downarrow)$ was .87. These statistics ignore, however, those trials where no change was made in the goal value. By changing the statistics to the probability of an increase in goal value given a win ($P(\uparrow/W)$) we find the probabilities shift downward to .50 and .44 respectively.[41/] Thus, while a shift in goal value seemed to be a good predictor of a prior condition, the prior condition is not a predictor of shifts in goal value.

Examination of the data and protocols for individual subjects indicates a major strategy difference among the subjects which will at least partially explain this fact. Some subjects clearly sampled the

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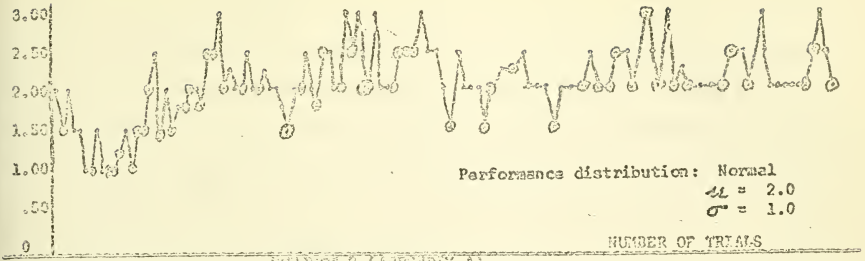
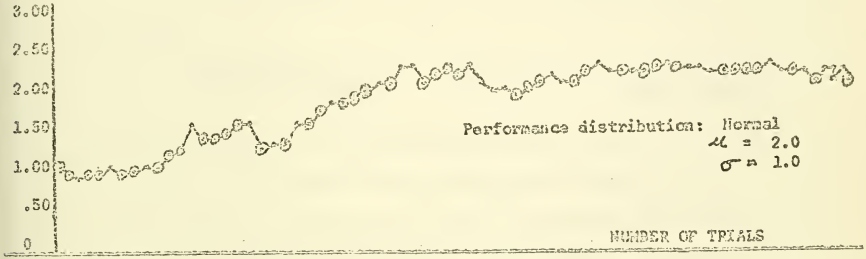
41/ The lack of symmetry in these percentages can be explained by the fact that the economics of the experimental situations was such that those who repeatedly used the same goal value tended to select goal values which would lose more frequently than win.

FIGURE 3

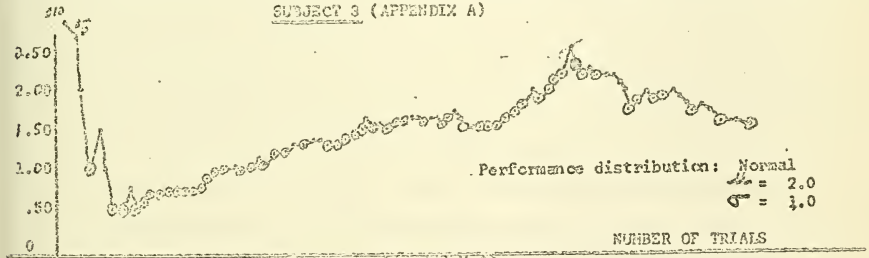
SUBJECT 1 (APPENDIX A)



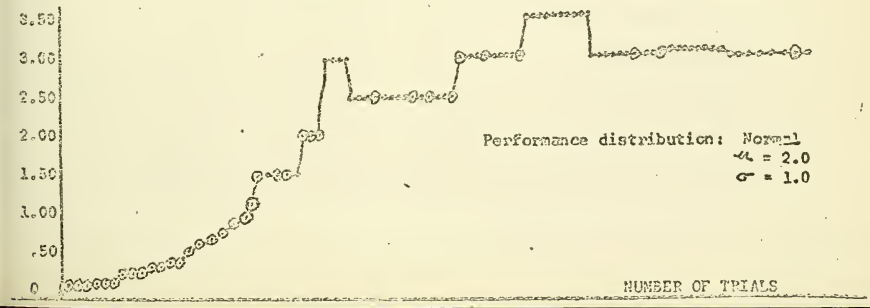
SUBJECT 2 (APPENDIX A)



SUBJECT 3 (APPENDIX A)



SUBJECT 4 (APPENDIX A)



consequences of a single goal value for a number of trials before modifying it. Some explicitly chose a sample size of 5 or 10 trials and did not appear to consider modifying the goal value within this sample. At the completion of the sample an evaluation procedure was used to decide whether to shift the goal value upward or to revise it downward. Two general evaluation schemes were used.

A few subjects (6) explicitly used an economic expected value of the form:

$$\text{Expected value of win at this goal value} = \text{Goal Value} - \frac{\text{Cost per Trial}}{\text{Prob. of Win}}$$

where the probability of a win was computed over all trials at the given goal value. If the result of this calculation was larger than the expected value which had been derived from a neighboring goal value, the goal value was shifted in the direction which indicated an increase in expected value and another sample of observations at the new value was drawn. The process was then repeated. Since the instructions indicated that the performance data was drawn from a stable probability distribution this procedure clearly will lead a subject following it to establish a goal value very close to that one which will maximize expected winnings for the experiment. Of the three general strategies observed in this situation, with respect to this attribute, this one was clearly superior.

Another set of subjects (11) used a sampling procedure which was somewhat less analytic than the above. These subjects explicitly defined a relative frequency of wins and losses to be their criterion and proceeded to sample in order to discover that goal value which yielded this frequency. For some, equal probability of wins and losses appeared

to constitute their objective. Others, however, recognized that the costs in the experiment were not symmetrically distributed with regard to wins and losses and so modified their frequency objective in the appropriate direction. For example, with a low cost of losing relative to the reward for a win, one subject used two wins out of five as his criterion for deciding the direction for his goal modification. If he won three out of five trials at a goal value he would increase the goal value and vice versa on one out of five. He did not modify the goal value if the sample frequency was two wins out of five trials. While strategies of this type could potentially bring the subject to choose goal values in the neighborhood of the economic optimum, this attribute of these strategies clearly depends upon the relative frequency of winning and losing at the economic optimum and the particular frequency selected by the subject as his criterion for goal modification.

While a few subjects were explicit about sample sizes none of them held consistently to their scheme--rather some sequential rule seemed to be used for determining sample size. Thus even among subjects who exhibited sampling behavior, i. e., repeated trials with no change in goal values, changes in goal value was in most cases predictable from the outcome of the last trial in the sample.

Ignoring those trials on which no change in goal value was made and recomputing the conditional probability of changes in goal value given the outcome on the previous trial we find $P(\uparrow/W) = .91$ and $P(\downarrow/L) = .86$. Thus by taking the outcome of the trial preceding a goal change as an indicator of the experience since the last goal change we find strong support for the hypothesis that goals move up with success

and down with failure. 42/

About half the subjects (15) made no explicit use of sampling in their goal modification process. They appeared to consider changing their goal value on each trial and seldom maintained a goal value at the same level for more than three trials. For the most part they changed goal values on each trial. 43/ It is interesting to note that this set of subjects was similar in another attribute of their behavior. The central tendency of their goal values as they approached the end of the experiment were very nearly identical to each other and to the median of the performance distribution--independent of variations in economic parameters.

Each subject was asked to indicate at the end of his participation in the experiment to choose a single goal value he would be willing to use if he were asked to repeat the experiment without an opportunity to change his goal value. Seven of the 15 subjects who did not use sampling chose exactly the median of the performance distribution while only one of the other 17 subjects chose this value. One hundred percent of these subjects chose values within one half of a standard deviation (of the

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42/ If we take as the null hypothesis that goal modification is independent of the outcome on the previous trial this hypothesis is rejected at the .01 level by the data of all subjects treated individually and of course, the pooled data as well.

43/ If we define a statistic named average sample size as the ratio of the total number of trials to the total number of goal changes this measure can be used as an indicator of each subject's tendency to sample. For example, if goal value changes were made on each trial the average sample size would be one, its minimum value. Individual subjects among the thirty two who participated in this experiment varied in average sample size from 1.02 to 9.55. Those subjects (15) who showed no explicit tendency to sample all had average sample sizes less than 1.75.

performance data) of the median while only 30% of the subjects who used sampling chose values in this range. If we take as the null hypothesis that the distinction between those who sample and those who don't will have no effect on the goal value they will choose at the end of the experiment we can reject this hypothesis at the .01 level.

Besides generating 9,000 trials of goal modification behavior, therefore, this series of experiments indicated the following general characteristics of the process:

1. Subjects tend to increase their goal value on success and reduce it on failure.
2. Subjects differ in their use of the concept of a sample in goal modification behavior.
3. Those subjects who did not use the concept of a sample appeared to seek the neighborhood of the median of the performance distribution e. g., 50% wins and 50% losses independent of the economic parameters of the experiment.

In attempting to relate these results to the theory which led to the design of this experiment we were led through the following analysis. In the theory, goal values constitute controls on problem solving processes, which in the experimental situation were entirely and intentionally suppressed. It was assumed, however, on those trials where a particular goal value led to the result "loss" that problem solving behavior would have been undertaken by the subject if the experimental situation had permitted it. It was also assumed in the theory that when the subject's goal value was successful, in that his performance exceeded it, problem solving behavior would not have been undertaken. As designed, the experimental situation could not yield evidence as to whether either

of these assumptions were correct. In reviewing the protocols and the data, however, another interpretation of the experimental situation seemed to offer some evidence on these assumptions.

If, instead of interpreting the value determined by the subject on each trial as a goal value which controlled his propensity to undertake problem solving, we interpret this value as the consequence of problem solving activity, the behavior of the subjects can be reinterpreted. Those trials on which the decision value was changed can be viewed as evidence of problem solving and those trials where no change in the decision variable was made could as a first approximation, be considered evidence of no problem solving. Under this new interpretation, we must find a process which controls such problem solving activity. We must find a process that will predict when problem solving will be undertaken and when it will not. To put it another way, we must find a process which will not only predict when the subject will be satisfied with his goal value and not undertake problem solving but also predict when he will be dissatisfied with a goal value and undertake problem solving. A search of the data from evidence of such a mechanism met with some difficulty, however.

Those subjects who used a sampling strategy in modifying their goal values behaved as though they were satisfied with the value they used over sampling interval, i. e., they did not change it. At the end of the sampling interval, however, they behaved as though they were dissatisfied with it, i.e., they changed it. This interpretation seemed a bit forced. It was difficult to believe from the protocols that the subject was satisfied with this goal value during the sampling process.

It seemed more reasonable that no value was ascribed to the decision value until the end of the sampling interval. But this problem was not felt to be so difficult, for reasons described below, as another aspect of the data.

The majority of the subjects rarely left their decision value unchanged from trial to trial. Under the new interpretation this implies that these subjects were always dissatisfied with their performance. Also it should be noted that their dissatisfaction seemed to run in two directions. Sometimes their problem solving led to a reduction of their decision value and sometimes it led to an increase. A new interpretation of the subject's decision process in this situation was required to explain these results. The hypothesis which was devised is following:

1. The subject develops two distinct problem solving operators.
2. One of these operators examines prior experience with respect to values at or below the current value and yields a decision which will reasonably increase the probability of a win on the next trial by lowering the current decision value.
3. The other operator examines prior experience with respect to values at or above the current value and yields a decision which will reasonably increase the value of a win should it occur on the next trial.
4. The subject associates these operators with certain stimuli which occur over the course of the experiment.
5. The subject's behavior can be understood (predicted) by discovering these stimuli and operators.

In the case of those subjects who modified their goal value on each trial the hypothesis that the stimuli for the "up operator" was the occurrence of a win and that the stimuli for the "down operator" was the occurrence of a loss predicts the direction of change in goal value in 1245 trials out of 1655 trials across 15 subjects. If those trials where no change was made are ignored the hypothesis predicts correctly in 1245 trials out of 1345. In the case of those subjects who used sampling procedures it is more difficult to generalize about the nature of the stimuli, but the following protocol data indicate that the hypothesis stated above was operating whatever stimuli the subject learned to associate with his up and down operators.

Protocol:

Subject C: I think I'll try a number more at $5 to see if I can up my gain on that. I think I will follow $5 to see how I will go.

[Trys $5 five times and wins five times]

Subject: I've won 100% at $5. I think I'll try $6 for a while.

[Trys $6 twelve times and wins nine times]

Subject: I'll have to go back to $5.

[Trys $5.20 five times and wins five times]

Subject: That looks pretty good. Next try $5.30, etc.

In the case of those subjects who made trial by trial modification in their decision value the associative hypothesis can be supported even more strongly. If the problem solving operators which modify the decision value have symmetrical effects in the sense that the expected change in each direction is equal, and if the subject takes the win-lose information on the last trial as the stimulus for using the respective operator, our hypothesis predicts that over the course of the experiment the decision value will tend to the median of a stable performance distribution. The prediction follows from the fact that as the decision value departs from the median in either direction the stimuli which the subject receives will tend to move the goal value toward the median. Thus over a series of trials the decision value will appear to seek the neighborhood of the median value of the performance distribution.

A comparison of changes in goal values for a number of subjects indicates the required symmetry in positive and negative changes. The tendency to the median was reported earlier. Thus the hypothesis is consistent with the observed behavior in a number of attributes. It predicts direction for those subjects who made trial by trial changes in 1248 trials out of 1285 trials and it predicts the tendency to the median exhibited by this same set of subjects. The hypothesis is also generally consistent with the behavior exhibited by those subjects who used a sampling strategy but the variation in stimuli which they used

make detailed prediction difficult.

There is one aspect of this hypothesis which is a bit disturbing, however. It predicts continuous problem solving on the single decision variable and offers therefore a rather limited explanation of the phenomenon of the problem solving control process, an understanding of which was the object of the experimental inquiry. In view of the empirical support for the hypothesis and the intuitive acceptability of continuous problem solving on a single variable when only one variable is available, it was decided to modify the experimental situation to permit multiple decision variables. The objective of this modification was to generate behavior which could permit an extention of the theory derived from the single variable case to the more general case of multiple variables. Since several other modifications in the experimental situation seemed desirable as well, the next chapter will be devoted to a description of the design of the second experiment.

VII. DESIGN OF EXPERIMENTAL SITUATION II

The principal reason for modifying the first experimental situation was to provide for the observation of behavior in a multiple goal situation. It was felt, however, that two other aspects of the first experiment could usefully be revised at the same time--the guarantee of stable random performance data which seemed to evoke sampling behavior, and the complexity of the reward scheme which seemed initially confusing to some subjects. Following a description of the second experimental situation some of the considerations which led to it will be discussed.

After reading a set of general instructions[44/] which indicated that the experiment would consist of a series of three separate situations, the subject read the instructions for the first situation. He was asked to imagine himself to be a contractor bidding on a series of contracts which would automatically be awarded to the lowest bidder. These contracts were being let on similar projects and a number of contractors had already indicated their bids for each project. The experimenter had before him a list of the low bids from all other contractors for the complete set of contracts which were to be let (50 or 75). The subject was told that the contracts were such that he was guaranteed a profit on each contract he won. In fact each contract would yield a fixed percentage of the bid price to the contractor who won the contract. Thus at the end of the experiment the subject could compute his "earnings" for his participation in the experiment by summing the bid price of all those contracts he won and taking a fixed percentage of that total.

44/ Appendix C.

Immediately after each bid the experimenter told the subject whether or not he won the contract but did not reveal the value of the "low" bid on his list. Thus the subject received only win-loss information over a series of trials. When the subject had completed his bidding for the contracts to be let, the first part of this experiment was complete.

The subject then read the instructions for the second part of the series. He learned as a result that the rules for the second part were essentially the same as those for the first one except that he was now to bid in two independent markets simultaneously i.e., only after he had recorded both bids was his performance in each market revealed. The markets were described as being completely independent of each other. And the low bids from other contractors against which the subject was bidding were described as "real" market data.

In order to simulate the simultaneity of the bids and the bound on the subjects attention and problem solving ability, one other restriction was imposed. On each trial (consisting of a bid in each market) the subject was required to keep his bid in one of the two markets the same as it had been on the previous trial. He was free to change his bid in either market on each trial but could not change both. When the subject had completed his bids in the second experiment in the series, he read the instructions for the third.

The rules for the third in this series of experiments differed from the second only in that the subject was required to bid simultaneously in three markets on each trial. The restriction of changing his bid in only one market per trial was continued. Thus the third experiment merely added another variable to the subjects environment while holding his

capacity to deal with these variables constant. When the subject completed his bidding in the third experiment he had completed the series. His earnings for the set of experiments were then computed and he was paid that amount for his participation.

In addition to this procedure, the instructions for this series of experiments also requested the subject to describe his process of bidding in so far as he could and these remarks were recorded. He was also requested not to discuss the game with other potential subjects.

The rules which have just been described were the result of some notions of what kind of situation was required to generate multivariate problem solving behavior and some trial runs with subjects which led to this final design.

Clearly the first experiment in this series created a situation virtually identical to that of the experiment described in Chapter V and which generated the behavior discussed in Chapter VI. The bidding situation where the subject faced "real" market data was intended merely to remove any guarantee of stable randomness in this data. The actual data was identical in both experiments.

The change to a fixed payoff percentage on those bids which won contracts and to a fixed number of contracts substantially reduced the initial confusion of subjects over that observed in the first experiment. In all other respects the first of the three experiments in the second series was identical to the first experiment. This was done primarily to corroborate or disconfirm the hypothesis which had been derived from the first experiment in the new situation and with new subjects. The results of this test will be discussed in the next

chapter.

The second experiment in this series injected the crucial difference between the first experiment and the second. Assuming that the subject would develop a set of problem solving operators and controls for a single stream of measures, the second situation imposed on him the necessity to allocate this problem solving ability to one of two situations for which it was presumably applicable. The second situation therefore yielded data on the problem solving control process. If goal values or a process generating them could be identified which would predict where problem solving would be allocated, then for the first time we would have an independent and therefore non-tautological theory of goal values and how they vary with performance.

The third experiment in the series was added to generate behavior in a similar but more complex situation than the second. It was felt that by adding to the demands for control on the goal modification process its mechanism might be more clearly demonstrated. To summarize, the first in the series of experiments was designed and run to insure that hypotheses about subject behavior derived from an earlier experiment held in a slightly different situation and with new subjects. The second situation was designed and run to force these subjects to deal with a situation which continuously exceeded their capacity to deal with it. It was hoped that this would yield evidence on the process whereby scarce problem solving ability gets allocated to variables in a complex environment. The third experiment increased the complexity of the environment in hopes of more clearly demonstrating the allocation process. The behavior which resulted from this series of experiments is discussed in the next chapter.

VIII. ANALYSIS OF BEHAVIOR IN EXPERIMENTAL SITUATION II

Nine subjects were run in the experimental situation II. Some of these (6) were, like those in the first experiment, drawn from among graduate students of the School of Industrial Management of M.I.T. The others (3) were students at the Harvard Business School. Examples of data sheets are included in Appendix D.

Since the three parts of situation II experiments are relatively separable, the behavior which they evoked will be discussed sequentially and then summarized.

Situation II - Part I

The experiment was run primarily to test the associative hypothesis, derived from behavior in Situation I, in a slightly different content and with different subjects. It was also intended to shed some light on the degree to which the sampling behavior exhibited in the earlier experiment was related to an explicit guarantee of stable, random performance data. We will discuss these results in the reverse order.

If we take the ratio of the total number of trials to the number of trials on which a change in bid price (called goal value in Situation I) as a measure of average sample size and accept this measure as an indication of the subject's tendency to use a sampling strategy, we find in Situation II, 7 of the nine subjects had an average sample size of less than 2.0 whereas only 15 out of 32 subjects had an average sample size of less than 2.0 in Situation I.

A straightforward analysis of these data suggests the hypothesis, that the withdrawal of the stability guarantee would have no effect on the subject's tendency to use a sampling strategy can be rejected at the .05 level. The selection of subjects used in these experiments was not well controlled, however, and we take this result to be inconclusive. [45/] Nevertheless the revised experiment yielded more data on the behavior of subjects who used trial by trial bid modification than we would have predicted from our experience in Situation I.

Turning now to the hypothesis that subjects relate distinct problem solving operators to cues in their environment we can compare the behavior exhibited by subjects in Situation II to that which we saw in Situation I.earlier. The specific hypothesis derived from experiment I was that the "search up" operator was associated with a win on the previous trial and the "search down" operation was associated with a loss, for those subjects whose average sample sizes were less than 2.0. In that case this hypothesis correctly predicted the conditions and direction u der which a decision value would be changed 87% of the time and the direction of change in decision value from prior conditions 70% of the time.

In the present experiment using the same criterion for selecting non-sampling subjects, this hypothesis correctly predicted the conditions under which a bid was changed upward on 97.5% of the trials across 6

45/ These results do suggest, however , that sampling behavior is either a function of explicit guarantees of stability or an educational experience which is rather rare in our society. For either of these reasons we might conclude that explicit sampling behavior may not be a very wide spread activity on the part of most managers.

subjects and the conditions under which a bid was changed downward on 92% of the trials across 6 subjects.[46] Thus the predictive power of the associative hypothesis is even greater in Situation II experiments than it was in Situation I.

With respect to predicting a change in bid from the results of the previous trial we find the prediction based on the associative hypothesis is again improved in Situation II. Whereas the $P(\uparrow/W)$ was .7% in the original experiment, in the revised experiment it was .83 and $P(\downarrow/L)$ changed from .68 to .92. We were led, therefore, to accept the hypothesis that subjects who did not use sampling explicitly selected their behavioral operator (search routine) on the basis of the results (win-loss) they had had on the previous trial. These conclusions are given further support if we admit the possibility of the up and down search routines yielding a zero increment. In this case the predictive power of the hypothesis goes up over 95% in all cases.[47]

In summary we appear to be able to conclude that the subjects' basic process was one of increasing their bids when they won on the previous trial and one of decreasing their bid when they lost on the previous trial. This hypothesis is empirically supported by two separate experiments, in which there was only a single variable in the subjects environment. To investigate the effect of adding another

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[46] The total number of trials of these six subjects in Situation II Part I was 565.

[47] If we take as the null hypothesis that goal changes are independent of the outcome on the previous trial we can reject this hypothesis in all cases at the .01 level.

variable to the environment, while problem solving capacity is held constant, we will look at the results of the second experiment in Situation II.

Situation II - Part II

Before building a hypothesis about the nature of the control process by which the subjects allocated their limited problem solving capabilities to the two variables in the experimental situation we first investigated how well the basic hypothesis held in this new situation. By looking at that market where a change in bid was made from the previous trial we can check the basic hypothesis, which predicts a win will preceed an increase in bid price and a loss will preceed a decrease in bid price. Performing this test we find that the $P(W/\not\uparrow)$ is .99 and the $P(L/\not\downarrow)$ is .95 over all subjects (9) who participated in the experiment. It is interesting to note as well that the average sample size for all (9) subjects in this second part of the experiment was less than 2.0 (Max. = 1.48) indicating a reduced tendency toward sampling in the more complex situation.

As a result of this analysis we were led to the conclusion that the basic hypothesis which predicts the stimuli and the operators which determine changes in bid prices continues to be supported in the second part of the experiment. We have shown that it is corroborated at least for those markets in which changes were made. Subject protocols indicated that they would have used this same procedure in both markets if they had been permitted to do so. A further check on this point will be described in the next chapter.

Assuming that we can predict the problem solving process which will be applied we can now investigate the control process by which these (now recognizable and predictable) problem solving operators are selectively applied to variable classes in the subject's environment. We can now look for evidence of a goal modification process on each variable which will perform this allocation.

Before looking at the data we might consider briefly what such a mechanism might look like in the context of this experiment. Assuming that the goal value (aspiration level) is defined with respect to each variable, we might expect it to be a function of recent experience on that variable. Thus, if we notice that problem solving is allocated to a variable each time a loss occurs, we might say under this theory that the aspiration level was "no losses" for this variable. We would then predict problem solving (down operator) to be applied each time this event occurred. If we also noticed that each time two wins in a row occurred, problem solving is applied to that variable, we might say the aspiration level for this variable was not more than two wins in a row without increasing the bid value. We might then predict that the search up operator would be applied each time this aspiration level was achieved.

Thus in the two variable situation created by this experiment we should look for four goal modifying mechanisms; one on each variable to control the up operator--probably defined in terms of wins at particular bid prices and one on each variable to control the down operator--probably defined in terms of losses. Evidence on the behavior of these mechanisms

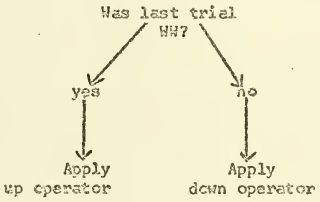
would be those situations where problem solving was allocated to a variable which had not violated a previous aspiration level e. g., application of the up operator to a variable which had had only one win since its last loss when under previous circumstances two wins had been required. In this event we would say the aspiration level has changed and set about to look for a systematic mechanism which controls such changes.

In examining the data and protocols which resulted from this experiment we found that the search for such a mechanism was a fruitless one. Partly as a result of this failure and partly as a result of protocol evidence, we turned instead to a somewhat different problem solving control mechanism. This mechanism is an elaboration of the associative process which seemed to work well in the basic hypothesis which resulted from the exploration of the single variable case. Using this approach we were led to search for a stable discrimination process which would predict the association of the events in the subject's environment with the available behavioral operators. Since there appeared to be less than complete consistency in this mechanism across subjects, we began by investigating the behavior of subject M. We started with the hypothesis that the allocation of problem solving is accomplished by a stable associative structure which discriminates among alternative problem solving operators by means of attributes of the subject's environment. Since in the case of a single variable environment, the attribute outcome on previous trial, had been a good discriminator between problem solving operators we began with this attribute.

In the two variable situation the variable outcome on the previous

trial, could take on four values: win in both markets; win in left market, lose in right market; lose in left market, win in right market; and lose in both markets. We coded these outcomes: WW, WL, LW, and LL.

From our previous work we could be fairly confident in hypothesizing that an "up operator" would be applied in the case of WW and a "down operator" in the case of LL. In the case of WL and LW the stimuli were mixed but we hypothesized that continued losses might be viewed as more serious than the opportunity costs of winning at a constant bid level so we predicted the application of the down operator in both these cases. These hypotheses can be described by the following process which can be applied to the outcome of each trial to predict the operator which will yield the bid on the next trial.

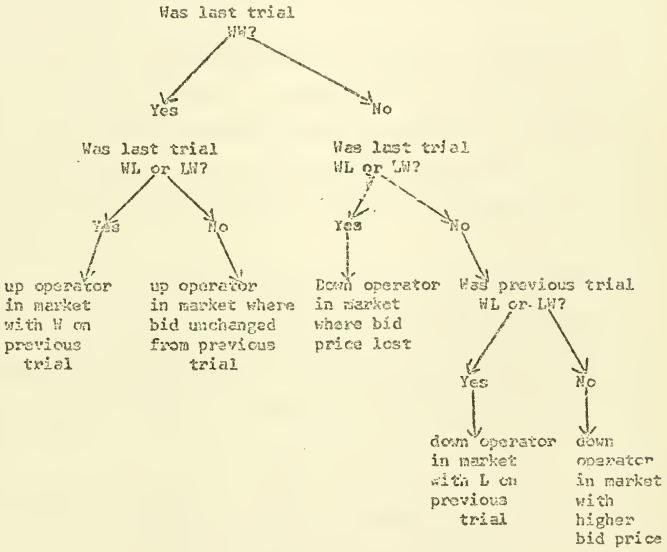


This hypothesis correctly predicted 69 out of 75 trials for subject M. If we take as the alternative hypothesis that on each trial the two operators would be equally likely to be selected, we would expect to predict 37 to 38 trials correctly on the average and to predict 69 out of 75 trials correctly far less than one time in a thousand. Thus as opposed to the equally likely hypothesis our hypothesis is strongly supported by the data.

It might be argued that the equally likely hypothesis is inappropriate for this comparison. It might seem more appropriate to compare the hypothesis we have suggested to a random process whose relative frequency of each operator was that actually exhibited by the subject. In this case as well, however, the random process is rejected. It predicts on the average only 40 trials out of 75 correctly and predicts trials 68 out of 75 correctly far less than one time in a thousand. In the absence of other reasonable hypotheses we are led to accept our hypothesis that problem solving operators were selected by the subject on the basis of the outcome of the preceeding trial.

We then attempted to elaborate our hypothesis to permit prediction of the particular market in which the operator would be applied. In the case of WL and LW this prediction is based on our earlier hypothesis that the subject would attend primarily to that market where he had lost on the last trial. In the case of WW and LL however, additional criteria were required to discriminate between the markets where the up and down operator respectively might be applied. We hypothesized that the subject would look next at the trial preceeding the last trial and attempt to select his market on that basis. In the case where the last trial was LL and the preceeding trial was WL or LW we predicted a continued attention to that market which had lost twice in a row. In the case of WW on the last trial and WL or LW on the preceeding trial we predicted continued attention to that market which had won twice in a row. In those cases where WW or LL were preceded by a WW or a LL this criterion would not discriminate among markets, however. In the case of LL we added the criterion that the down operator would be applied in the

market with the higher bid price and in the case of WW we assumed that changes in bid prices would alternate from market to market. These additional hypotheses can be described by the following process which can be applied to the outcome of each trial to predict both the operator which will yield the bid for the next trial and the market in which it will be applied.


Was last trial WW?
Yes
No
Was last trial WL or LW?
Was last trial WL or LW?
Yes
No
Yes
No
up operator in market with W on previous trial
up operator in market where bid unchanged from previous trial
Down operator in market where bid price lost
Was previous trial WL or LW?
Yes
No
down operator in market with L on previous trial
down operator in market with higher bid price

This hypothesis correctly predicted the operator and the market in 56 out of 75 trials. If we take as the alternative hypothesis that on each trial it was equally likely that each operator would be applied and equally likely that each market would be selected for this application

we would ecpect to predict about 19 trials correctly out of 75 trials and to predict 56 out of 75 trials correctly far less than one time in one thousand such experiments. As opposed to the equally likely hypothesis, our hypothesis is strongly supported by the data.

If we take the actual frequencies of the various choices made by the subject rather than the equally likely hypothesis we find an expected frequency of 20 and that once again our hypothesis is supported at beyond the .001 level.

We found we could further test our hypothesis on another aspect of this subject's behavior. By analysis we can predict the relative frequency of wins and losses which our hypothesis will generate when it reaches equilibrium on a stable probability distribution. We can then examine the subjects experience to test its consistency with this result.

If we take as the equilibrium point on the performance distribution that point where our hypothesized process of bid modification is equally likely to apply an up or a down operator, we can compute the relative frequency of wins at that point by solving the following equation:

$$p^2 = 2[p(1-p)]^2 + (1-p)^2$$

where p = probability of a win at equilibrium

p^2 = probability of WW in independent markets

$1-p$ = probability of a loss

$[p(1-P)]$ = probability of WL or LW in independent markets

$(1-p)^2$ = probability of LL in independent markets

We find that p equals .71 or that in equilibrium our hypothesized process

will win 71% of the trials.[47] Before comparing this frequency to that present in the subject's data we designed the test which we would apply. The experiment consisted of 75 trials in each of two markets or 150 observations of the events win or lose. The hypothesized process predicts on the average that 71% or 106 of these events will be "win." The variance of this prediction can be approximated by the binomial form:

$$\sigma^2 = np(1-p)$$

where $n = 150$ trials

$p = .71$ the hypothesized frequency of the event win.

Evaluating this expression we find

$$\sigma = 5.6 \text{ wins}$$

Using this result and the normal approximation to the binomial we can compute a 95% confidence region about the mean of 106 which extends from approximately 95 wins to 117 wins. If the observed number of wins lies within this region we will have no basis (at the 5% level) to reject our hypothesis of the control process. The actual number of wins in subject H's data was 106 wins out of 150 trials.

Using essentially the same hypotheses[48] developed for subject H we were able to reproduce the results reported for subject H on subject G's data.

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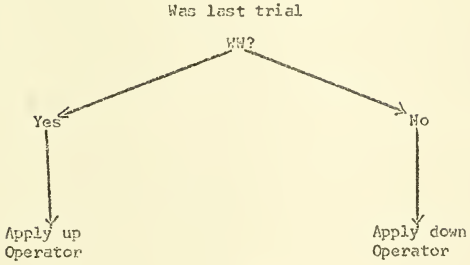
[48] It is interesting to compare this equilibrium with frequency of winning that wasfound (and predicted) for the single variable experiment of 50%.

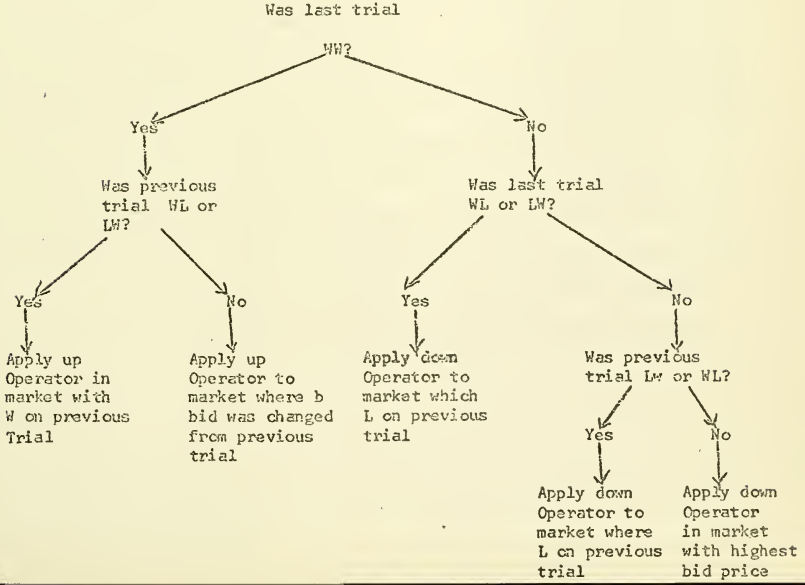
[49] The only change was that when WW was preceded by a WW or a LL subject G continued to attend to the same market rather than alternate.

The direction hypotheses shown below



correctly predicted 41 out of 50 trials and the random hypothesis was rejected on this aspect of the subject's behavior at the .05 level.

The combined hypotheses


Was last trial
WW?
Yes
No
Was previous trial WL or LW?
Was last trial WL or LW?
Yes
No
Yes
No
Apply up Operator in market with W on previous Trial
Apply up Operator to market where b bid was changed from previous trial
Apply down Operator to market which L on previous trial
Was previous trial LW or WL?
Yes
No
Apply down Operator to market where L on previous trial
Apply down Operator in market with highest bid price

correctly predicted 35 out of 50 trials while the random hypothesis for direction and market was rejected at beyond the .001 level. Computing the number of wins predicted our hypothesis in 100 trials we found the range 62 to 80 should include the number of wins 95% of the time. In counting the number of wins in the subject G's data we found 66.

We repeated this process for subject S with the identical hypotheses and tests as those used on subject G and got essentially the same results. Thus for three of the nine subjects run in Situation II, we found rather strong statistical support for relatively complex hypotheses. We concluded, therefore, that for these subjects at least, the problem solving control process could be simulated by a relatively stable structure by which problem solving operators were associated with specific local stimuli in the subject's environment.

We were encouraged by these empirical results. They seemed to indicate that a stable associative process could account for dynamic problem solving behavior in a complex environment. However, in attempting to extend this analysis to other subjects and to other and more complicated environments (like the three market bidding situation) we found it impossible to discover such simple mechanisms with similar predictive power. We were led therefore to theorize about the process by which the associative process which we were hypothesizing might itself be generated.

In 1958 a study of the process of learning nonsense syllables produced a theory of the process whereby complex associative structures

evolve from experience. [50/] It seemed possible to apply that theory to the present situation. Feigenbaum was able to show that a stream of performance information and a well defined procedure for processing this information, could yield after some time a rather complex process which would associate specific stimuli with specific responses which were correct within the context of his experiment. He called this process EPAM and found independent empirical support for the hypothesis that it captured some of the major elements of the behavior of human subjects in the classical nonsense syllable learning situation.

While it may be heresy to those rationalists among us, the behavior of subjects in the bidding experiments seemed sufficiently similar to nonsense syllable learning to suggest that an EPAM - like process might provide a working hypothesis at least for what some might be willing to describe as maximizing behavior. In the learning theory (EPAM) the subject receives information on his performance in the form of right-wrong replies depending on his responses to the given stimuli. When the response is right no elaboration of the discriminating process takes place. When the response is wrong the subject adds discriminating power to his associative process in the form of more detailed tests on the stimuli. Over a number of trials the subject developes an associative process powerful enough to discriminate among all stimuli in the experimental environment and the process ends.

In the bidding situation a subject appeared to learn to associate

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50/ Feigenbaum, E. A., "The Simulation of Verbal Learning Behavior," Computers and Thought, E. A. Feigenbaum and J. Feldman (eds.) McGraw Hill, 1963.

particular problem solving operators with particular stimuli in a similar manner. On each trial he learned whether the behavior just executed was right (win) or wrong (lose). The situation was somewhat more complicated than this, however, in that winning and losing did not always imply the same thing about the behavior. Winning at a high bid was somehow better than winning on a low bid and as a result the subject's behavioral search was not so simple as one of simply discovering a set of behaviors which would lead only to wins.

The bidding situation was also more complicated in another sense. Because of the randomness in the response data, the same behavior in very similar circumstances could easily yield different outcomes. The associative process in this situation would therefore have to be able to cope with this kind of noisy feedback. Thus in some ways the bidding situation differed from the conditions under which EPAM - like process which generates those relatively stable, associative structures which we were able to discover in the case of several subjects.

This hypothesis is also able to provide a tentative explanation of why such simple structures could not be discovered for all subjects. The experimental situation is a novel one, and it would be unlikely indeed that any of the subjects have well developed routines available for dealing with it. It seems possible therefore that the development of an associative structure might still be taking place over the course of more than one hundred trials, especially in view of the fact that the feedback was noisy. Thus we might explain our inability to demonstrate the associative nature of the problem solving control process hypothesizing that no single associative process is used over the course of the experi-

ment by most subjects because they are involved in the trial and error process of learning one.

This explanation hardly constitutes a proof of the hypothesized structure, however. To submit this hypothesis to an empirical test another series of experiments was designed and conducted. In most respects this series (Situation III) of experiments was identical to those just discussed i. e., the subject was asked to make sequential bids in one and two market situations where his problem solving ability was limited to a single market per trial. The reward system for these experiments was modified slightly however. Instead of being paid on the basis of his bidding behavior each subject was permitted to bid in each market situation until he could devise a rule by which he would be willing to play. When satisfied with the rule he had written down, the subject's earnings were computed by applying the rule to the next series of contracts. Thus the subject was forced to explicitly define a stable process by which his earnings would be determined.

One advantage of this procedure was, of course, that it permitted the subject to define when his period of learning (net modification) was essentially complete. Another and perhaps more important advantage was that by examining the resulting mechanism we could observe directly the structure of the problem solving control process which had evolved from the subject's experience. We are not so naive as to believe that this procedure did not affect the process being observed. It seems quite likely that the pressure to devise a rule would force the subject to regularize his bidding more so than if no routine was expected of him. In addition it seems quite unlikely that the process of con-

tructing a control process has well defined end point such that from then on the subject's play would "naturally" have been completely consistent with the response generator he described. Therefore, rather than looking on the rules which resulted from this series of experiments as indicative of final design we look on them rather as cross sectional evidence on an on-going process.

The aspect of the experimental situation which permitted this kind of analysis was its extreme simplicity. The subject could easily consider all possible outcomes on each trial and list the responses he would make to each. Thus it was conceivable at least that on each trial the subject could have defined a rule for his bidding on the next trial. In the series of experiments just described he was asked to record only one of these rules at that point in his experience where this rule was changing relatively slowly. Observation of such a rule was therefore clearly not viewed as an invariant parameter of that subject who wrote it, but rather a direct observation on the form of the process by which he allocated his problem solving capability to an environment whose complexity exceeded his abilities to deal with all aspects of it simultaneously.

Ten subjects participated in this final series of experiments. Four of them were undergraduate engineering students at M.I.T. and the remainder were undergraduate management students at Northeastern University. The rules for bidding which they recorded are shown in Appendix E.

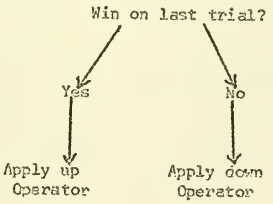
The hypothesis that these rules would be in the form of discrimination processes which would associate relatively simple stimuli

with relatively simple behavioral operators was confirmed in every case. The rules written by subjects F and L are shown below with a flow chart of a discrimination process which will yield the same behavior.

1. Rule written for single variable experiment by subject F:

"Start at $1.00. If you overbid (lose) lower by $.25 until you are underbid (win). If you underbid on first bid increase bid by $.50 until you are over it. Lower bid by $.25 if lose etc., until wins by underbidding and then increase bid by $.10. From then on if last bid was overbid increase by $.05 from last successful bid. If successful in 2 successive bids increase to $.10; if not successful on the $.10 increase, return to $.05. If not successful on any particular bid decrease by $.02 for next two bids and then by $.05 for next two and then $.10 until you underbid."

Goal Structure

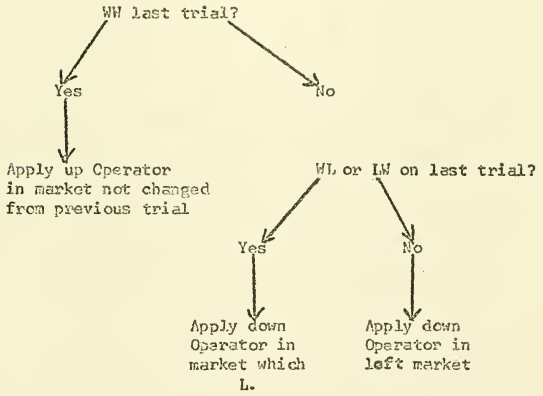


Rule written for two variable experiment by subject F:

"Start at $1.00 if you overbid (lose) in both markets lower left by $.25 until underbid then right. If you underbid (win) in both markets on first bid increase the bid in the

right market by $ .50 until you are over it (lose). Lower bid on right by $.25 if lose etc., until wins. After successful bid in both markets after lowering of $.25 increase of $.10 in both markets (right first). If successful in right market and not left, decrease left until successful in it. If not successful in 3 bids decrease (by) $.10. After success in left, increase right $.05 for two turns and then to $.10 if still successful. If unsuccessful in both markets decrease $.05 in left until successful."

Goal Structure

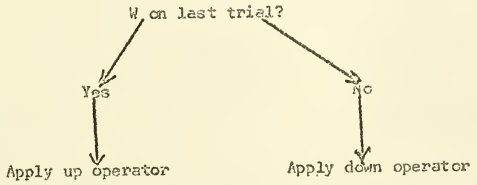

WW last trial?
Yes
No
Apply up Operator in market not changed from previous trial
WL or LW on last trial?
Yes
No
Apply down Operator in market which L.
Apply down Operator in left market

The goal structures described by subject F are virtually identical to those we had hypothesized for subjects M, G, and S without their describing them.

2. Rule written for single variable experiment by subject L.

"Start at $1.20, then for each correct (win) number (bid) go up $.10. For each incorrect (lose) number (bid) drop $.15.

Goal Structure

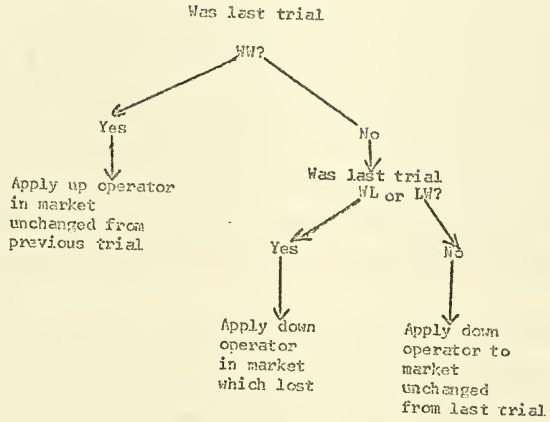


Rule written for two variable situation by subject L.

"Start at $1.10 (both markets) + $.10 each correct number - $.20 each incorrect number.

If win and lose, drop lose and raise as soon as wins two times. Then alternate L. R.

Goal Structure



This same mapping is possible in the case of all (10) subjects. We accept therefore the hypothesis that the process of problem solving control is a discriminating process which associates events in the environment with specific problem solving operators. The implications of this result will be discussed in the next chapter.

VIII. SUMMARY AND CONCLUSIONS

By creating extremely simple experimental situations, it has been possible to demonstrate that subjects allocate their problem solving ability to variables in their environment by means of relatively stable discriminating functions defined over attributes of this set of variables. Since this theory differs somewhat from hypotheses which have been suggested for this process, it seems worthwhile to consider some of the implications of this revision for concepts arising from those hypotheses.

The concepts of satisfaction and dissatisfaction have been held to be the states of the organization which controlled problem solving activity. In the early stages of our investigation, a mechanism was sought which would independently predict these states on the variable(s) in a subject's environment. By examining some of the data from the two-market bidding experiment, however, we can see that the way these concepts have been used can be misleading.

Having previously shown that in the single market case the subject applied an up-operator to the bid price when he was successful in his prior bid and a down operator when he failed to win, we ran a few trials of subjects in the two market situations with no constraint on their problem solving ability i.e., they could change their bids in either or both markets on each trial. We found in all cases that they continued to use the same associative process which they had established in the single market case--applying it independently to both markets. It was only when a constraint was placed on their problem solving

ability that their behavior changed. As a result of the constraint they could only apply a problem solving operator to one of the two markets and we found that they dealt with the increase in complexity by elaborating the discrimination process with which they selected the problem solving operator. It is important to note, however, that as a result of the constraint they were forced to behave as though they were satisfied with their performance in that market which did not receive attention. Their earlier behavior indicated quite clearly, however, that they were not satisfied i.e., given the opportunity they would have changed their bids in both markets. Thus satisfaction with most variables in a multiple variable environment is a logical consequence of the fact that the decision maker can attend to only one problem at a time and is determined by the process of problem solving control rather than a determining factor in it.

Another aspect of the satisfaction or aspiration level theory of problem solving control was that aspiration levels were seen to rise on success and to drift downward on failure. In behavioral terms this implies that problem solving will continue even in the face of improving conditions and that problem solving might be more persistent on variables whose performance is declining. Within the context of a theory which required violation of an aspiration level to trigger problem solving these effects could only arise if the level of aspiration had some rather particular dynamic properties.

Within the theory we have proposed, however, no such dynamic mechanism is required. Problem solving activity is assumed to be continuous and the associative process merely allocates it to various

aspects of the environment. Thus it is predicted by our theory that problem solving will continue in the face of improving conditions, and further that problem solving may very well be persistently applied to variables in the environment whose performance is declining. In this theory, however, no dynamic mechanism is required. A relatively static associative process will interact dynamically with a changing environment if the rate of problem solving activity is taken as a constant instead of a variable.

Besides acting as triggers for problem solving, aspiration levels have also been useful in theorizing about the stopping of problem solving. The whole notion of satisficing has grown up around the concept of a level of performance on a particular variable which is somehow "good enough." It is interesting to see how this concept can be handled in terms of the proposed theory. Two mechanisms are suggested. 50/ The first is that of a behavioral operator with a "natural" end point. We might take driving a nail with a hammer for an example. We do not have to consciously limit how far we drive a nail with a single blow of a hammer under most circumstances because the wood does it for us. Each application of the operator "hit the nail" moves the nail only so far and this constitutes a natural end point for the operator. We can then decide whether we want to apply the operator again or stop. To do this we use the second mechanism, and the one to which the experimental work of this study is devoted.

51/ These mechanisms have also been suggested in Miller, G. A., Galanter E., and Pribram, K. H. Plans and the Structure of Behavior, Henry Holt and Co., New York, 1960

We ask ourselves to which variable in our environment we wish to apply our problem solving abilities next. If "hitting the nail" is not called forth by this process we do not hit it again. We do something else. Thus, as a result of the fact that the problem solving process can deal with only one variable at a time, a start rule for the next variable automatically is a stop rule for the previous variable and no separate mechanism is required.

The above analysis indicates that a stable, associative process defined over the attributes of the decision makers environment can be substituted for those mechanisms which have been hypothesized with respect to theories of behavioral controls based on independent aspiration levels. In view of the empirical evidence in favor of this associative theory we are led to conclude that this may constitute a more fruitful framework for studying decision behavior than the earlier theory. We are further encouraged in this conclusion by the fact that our theory seems to explain phenomena in addition to those which have been ascribed to the aspiration level phenomenon.

In their book, A Behavioral Theory of the Firm,[52/] Cyert and March describe the need for a theory of focussing in addition to a theory which will predict the starting and stopping of problem solving.

> "Since not all demands receive attention at the same time, one important part of the theory of organizational objectives is to predict when a particular unit in an organization will attend to particular goals. . . . Whatever the experience it shifts the attention focus."

52/ Cyert, R. M. and March, J. G. Op. cit., pp. 35

Clearly the theory we have proposed will serve both as a focussing mechanism and as problem solving control process because we have suggested that the two processes are identical. The process by which problem solving ability is allocated to variables involves a scanning of other variables. It clearly therefore serves the focussing function thought to be required in addition to an aspiration level theory of problem solving control.

Some evidence supporting the hypothesis that the associative structure we are proposing is reasonably stable and to a degree predictable is indicated by a study performed by Simon and Dearborn.[53/] After presenting a group of industrial executives with a description of a rather general business situation, they found that the problems recognized by these executives were highly correlated with the individual executive's professional experience. Our theory would predict this result if we assume that in their years of experience these executive had built associative structures and problem solving operators which were highly specific to their particular function in the organization. Thus accountants would see control problems, production managers would see scheduling problems, and treasurers would see cash problems in the same situation simply because these were the specific associations they had learned to relate to the rather general stimuli.

53/ Dearborn, D. C. and Simon, H. A. Selective Perception: A Note on the Departmental Identification of Executives, Sociometry, 1958, 21 pp. 140 - 144.

We have now proceeded from a question of how solutions to problems might be implemented, through an investigation of the process by which problems are defined, to a theory which suggests behavior is related to a changing environment by means of relatively stable associative mechanism. We are now in a position to reexamine the question which started this investigation. In the next chapter, we will discuss some particulars of an attempt to modify behavior by means of implementing a scheduling system in a small factory and an attempt to relate our theory to some of those theories of this process which we discussed in Chapter II.

IX. AN APPLICATION OF THE THEORY

In the summer of 1958 we had the opportunity to spend several weeks in a factory whose manager had initially undertaken the use of a rather sophisticated scheduling system about three years before. The purpose of our visit was to reevaluate the cost parameters upon which the recommendations of the system were based and, as a result, we talked at some length with most of those people in the factory who had been connected with the application of the system. Much of our description of the process of this application is based, therefore, on reports of people who participated in it rather than our own observations.

Our initial contact was with the factory manager who described in some detail his part in the development and implementation of the system. Independent of what his efforts may have contributed, he had strong personal feelings of participation in both these processes. He was pleased that the system had "worked out so well." From our initial discussions, we got the distinct impression that the scheduling system was making a real contribution to the plant's operation.

Having been assigned working space in the production scheduling office, our next contact was with the clerk assigned the responsibility for the computational work connected with the scheduling system. He gave us quite a different picture of the effectiveness of the application. Each month it was his responsibility to compute the aggregate work force and production rate implied by the system for the coming month. Based on these results and information on the current stock levels and orders for the various items in the product line, he converted the aggregate

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Having been assigned working space in the production scheduling office, our next contact was with the clerk assigned the responsibility for the computational work connected with the scheduling system. He gave us quite a different picture of the effectiveness of the application. Each month it was his responsibility to compute the aggregate work force and production rate implied by the system for the coming month. Based on these results and information on the current stock levels and orders for the various items in the product line, he converted the aggregate

figure on production rate into item quantities by means of a well defined allocation procedure. Using a batch size rule he then converted each of these item amounts into numbers of batches of specific sizes and prepared a production ticket indicating raw materials quantities and processing specifications for each batch. Upon completing these tickets, representing the production which the system called for during the coming month, he hung them on a peg board in the production scheduling office where they could be drawn by the various plant foremen who controlled the particular sequence in which the plant equipment was to be used. In most respects the system which the clerk described sounded like a well established and effective application of the scheduling system. We looked forward to examining its economics in more detail. The clerk then described what seemed to be a defect in the system: the foremen never used the production tickets which the system yielded.

As it turned out "never" was too strong a word. We learned that the foremen actually decided on the particular product and the quantity they wanted to make before coming to the production office for a ticket. They would then look through the tickets which the scheduling system had yielded and if they found a ticket which matched their needs they used it. If, however, the system had not yielded the ticket which they felt they needed, they asked the clerk to prepare one for them to use. Examination of a file of unused tickets for previous months indicated that about half of the production carried out in the factory was on tickets which the scheduling system had yielded automatically and the other half was performed on tickets specifically requested by the foremen. By considering this fact alone, however, it would be easy to

overestimate the influence of the scheduling system on the item production decisions in the factory. So far as we could tell the foreman's decisions with respect to what would be produced were made quite independently of the output of the scheduling system.

In an attempt to get some insight into the reasons behind this flaw in what otherwise seemed to be a model scheduling system we spent considerable time talking with several foremen. As they described it their environment was very complex. The process by which they decided what to produce included consideration of inventory levels and orders for the various products, the physical capabilities of individuals in their crew, union contract clauses regarding job descriptions for various classes of employees, technological limitations on the flexibility of process equipment, cost controls on labor utilization, special rush orders from customers or salesmen, opportunities to "work-off" obsolete inventory items in current production batches, limitations on certain kinds of service equipment like buggies, scales, etc., and many others. By accepting their perception of the decision situation, it was easy to understand the process by which they decided which product, and what quantity to produce. Foreman appeared to arrive at a decision as to which problem solving operator (produce a batch of Product P of size Q) to apply by a process of discrimination based on attributes of their environment. Through their years of experience, the foreman's discrimination processes had become highly specific and they described no difficulty in deciding what to do next. In fact, it was an important part of their job to make this decision.

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The output of the scheduling system in the form of a fixed set

of batch tickets complicated this job, however, for it reduced the set of problem solving operators available to the foremen (if they wished to follow the recommendations of the system). It implied that the attribute "batch ticket on schedule board" would have to be added to their discrimination process at some point prior to choice. This in turn implied that certain other attributes might have to be excluded from the choice process. In the foremen's words these were "things the system didn't take into account." In the process of implementing the system, however, these conflicts had been removed. As it has been explained to the foremen, the new scheduling system was intended to help, rather than hurt them, and they were instructed to use their judgment to override the system if they felt it necessary. As it turned out, they felt it necessary indeed, and half the production in the factory turned out to be an exception to the scheduling system.

We then looked into the labor control side of the scheduling system. Each month, the clerk who performed the scheduling calculations, sent the recommendation of the system to the plant superintendent. In comparing the record of these recommendations to the employment records we found few instances where they agreed. To investigate these discrepancies we talked at some length with the plant superintendent.

With responsibility for the manufacturing operations in plant, the superintendent, too, faced a very complex environment. The peculiarities of the union contract made the internal flexibilities of the work force somewhat limited. Training allowances, and seniority structures had to be considered in most internal transfers. Labor grievancies with respect to work assignments, pay rates, and work methods took up a large amount of his time. Most external pressures for rush orders and

inventory control were exerted on him. He worked closely with the foremen on these problems. He saw his problem of labor control primarily as one of satisfying the demands of the factory budget. The foremen expected to have the budgeted labor content of the production they scheduled available when they needed it and the plant manager expected these costs to be reduced when they were not being transformed into product. The use of overtime was one of the variables he could use to satisfy these demands but the factory budget placed a monthly limit on the amount of overtime he could schedule so there were times when he felt he lacked even this degree of freedom.

He appeared, however, to have a very positive attitude toward the scheduling system and said he tried to follow it when he could. He, too, understood that the system was designed to help him and he thought that perhaps it did. He had also been told, however, not to follow the recommendations of the system blindly. He was to use his judgment and deviate from the system when he had to. Deviate he did "because the scheduling system didn't take enought things into account" and the impact of the system on the decisions made with respect to workforce size was modest indeed.

We concluded as a result of our discussions with the foremen and the plant superintendent that the scheduling system was having virtually no impact on factory operations and we reviewed this conclusion with the factory manager. He disagreed. He felt that the system was working admirably. Those people in his organization who were responsible for the decisions it provided, all had the benefit of its recommendations--after all, half the batches in the plant were made on tickets which the system had generated. There were deviations to be sure from the details

of its recommendations but this was to be expected. The rule could not possibly respond to day to day demands which the plant organizations had to satisfy. He felt not only that the rule was being used but also that it was making a valuable contribution to factory operation.

We were at the time somewhat perplexed by what we had found. From what we had heard and to some extent at least, observed, we were forced to conclude that the implementation of the scheduling system had failed to influence the behavior of the plant organization. On the other hand, we found no evidence of resistance to the use of the new system. Everyone was agreed that its objectives were highly desirable and felt that although it had not been of much benefit to their particular part of the organization they were sure it had helped others and that its overall effect must have been beneficial. It would require a very parochial view to consider this attitude one of resistance.

In reviewing the process by which the system had been introduced we found no explanation for its modest effect. The manager had strong feelings of participation in its design and a series of meetings with plant personnel had apparently satisfied any fears they may have had about the consequences of its adoption. Thus with respect to those theories of the change process which assert that participation is a necessary step, this case seemed to satisfy the theoretical requirements--yet no change had taken place.

Examining the situation from the point of view of the behavioral model we have proposed, however, the impact of this scheduling system on this factory organization becomes not only understandable but predictable. The scheduling system was essentially generating solutions to problems

which did not exist--or more accurately, it generated solutions to problems which the associative processes used by the decision makers in this factory did not generate. The reasons for this discrepancy were clear. The particular attributes of the environment to which these two systems responded were not identical. The scheduling system responded to aggregate and item inventory levels, workforce size, a twelve month sales forecast, and a variety of cost estimates. The foremen and the plant superintendent on the other hand respond to aggregate and item inventory levels, budget constraints, special requests for service, availability of equipment and personnel, etc. These differences between these sets of stimuli should not be over emphasized, however. They are clearly not independent. In fact, E. H. Bowman has found [54/] that if the high frequency transients of organization's response systems are removed, that their behavior approximates very closely that implied by models based on economic analysis of those situations he has examined.

This result largely confirms the observations that we had made. Individuals in the factory we observed unanimously agreed on the ultimate objectives which the system was attempting to accomplish and, if we examine a comparison of their behavior with that implied by the scheduling system they used for the same time period, we find that with respect to low frequency responses the two systems exhibit quite similar responses. We conclude therefore that not only did the two systems agree with respect to long-run objectives to a considerable degree, but also

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54/ Bowman, E. H. "Consistency and Optimality in Management Decision Making, Management Science, January 1963. pp. 310-321

their "average" behaviors were consistent with these objectives and each other's.

If benefits are to be derived from the application of the scheduling system of this kind, therefore, they must come from its impact on the high frequency responses of the organizations scheduling process. That is implications of the scheduling system must become influential at the point where the detailed decisions with respect to production and labor control are made. In the context of our theory this can only be accomplished if by some process the recommendations of the scheduling system can be added to the discrimination process by which decision makers in the organization select the particular behavioral operators they will apply in a given situation.

It now seems clear why the scheduling system had such modest impact on the behavior of the factory we observed. If we think of that process by which the decision maker selects his problem solving operators as his judgment and recall that in all their discussions of the scheduling system the foremen and the production superintendent were told to use their judgment instead of the system recommendations where there was disagreement between the two, we find that this instruction virtually precludes the possibility of the system's having an impact on their behavior.

The issuing of such an instruction seems to arise from a misunderstanding of the behavior selecting process. If this process were non-specific in that it could not discriminate precisely which problem solving operator to apply to a given situation, then we might expect that the addition of criteria (like the output of the scheduling system) would help the decision maker make a choice. We have observed, however, even

in these simple situations we created in our experiments that in order to control the application of problem solving operators, a discrimination process had to be developed which would yield a unique result. Attributes on the environment were defined and added to an associative structure until such a discrimination was possible. Thus we would expect that the foremen and the plant superintendent had well developed discrimination processes which would yield a unique problem solving operator in a given situation and that as a result the scheduling system either agreed with this output (a ticket on a peg) or it would violate the decision maker's judgment and lead him to request a special ticket. The problem of implementation in this case, therefore, is to make the output of the scheduling system an attribute in the process of problem selection rather than something to be compared to its output. We would predict on the basis of this argument that if this were accomplished, the scheduling system would begin to influence the behavior of the factory organization.

A visit to the factory in 1961 confirmed this prediction. Sometime during 1959 the calculations involved in the scheduling system were transferred to a central data processing facility. This facility then began issuing the recommendations previously issued by the schedule clerk. Workforce recommendations were made monthly as before but there was a change in the system which generated the production orders. Priority lists were prepared daily of those batches of product which the system judged to be required most urgently. In order for this system to work, however, it was necessary for the factory to send reports of batches completed to the data processing center so that they could up-

date their priority list. If the factory produced an item on the list, it was dropped from the next day's list. If it was not produced, however, it was carried forward to the next day's list. The priority system was such that when the factory did not produce items on the list the list grew in length.

In many respects this change in the scheduling system might have been trivial for if foremen could ignore tickets on pegs they certainly could ignore items on lists. The real change in the system resulted from the fact that they weren't permitted to ignore the lists. People from the data processing center were interested in their system being effective. As a result when the factory deviated from their recommendations they pursued the matter with the foremen, the manager, and even higher levels in the organization. They forced the foremen to defend their behavior when they deviated from the rule--which they could do in each special case. But they found the need to do so annoying and began therefore to consider this attribute of their environment when they were selecting batches and quantities to produce. It was not surprising that as this attribute was added to their discrimination process their behavior began more and more to satisfy this new constraint on it. We might guess that they saw this change not so much one of following recommendations of the rule as one of avoiding conflict with data processing personnel who had become another "consideration" in the factory's scheduling process. For what ever the reason, however, when we visited the factory in 1961, the production decisions in the factory were essentially those recommended by the scheduling system.

As a control on this "experiment" we can examine the labor control aspect of the scheduling system in 1961. We found that the data

processing personnel had not taken the same interest in labor control that they had taken in production control. This may have been because their system was not so obviously distrubed by deviations in this variable or because others in the organization (accountants) were clearly charged with primary responsibility in the area of labor cost control. The accountants also did not concern themselves with this output of the system because they looked on the factory budget which they prepared as a satisfactory tool for detailed labor control. Thus with respect to labor control the system continued to yield dispassionate recommendations and the production superintendent was in no way induced to include these results into his behavior selection process. Our theory would predict that with an environment that is rich in other attributes to which his behavior might be associated that this information would have no effect--and so far as we could determine it did not.

Clearly these observations and reports of people working in a single factory constitute evidence which is, neither specific enough to strongly support the theory developed experimentally, nor general enough to suggest that the theory might be able to explain all such situations. It does suggest we believe, that the theory may be a useful framework within which to analyze and design attempts to modify decision processes. It suggests that, rather than ultimate objectives, the local stimuli which are the attributes of the behavior selection process are the critical elements in the change process.

This result is, of course, not inconsistent with the human relation theories regarding the efficacy of participation. If in fact the anticipated reactions of other people to certain behavioral alternatives

constitute important attributes of the behavioral selection process than clearly information regarding changes in their expectations, which might arise through interactions such as the process of designing the details of the change, would be important parts of the change process. the theoretical framework which we propose, however, suggests criteria by which one might select a set of participants who would be effective with respect to a particular change in decision processes. It also suggests that the effects obtainable through participation could conceivably be synthesized by adding or subtracting attributes relevant to behavior selection. We might suggest therefore that the following hypothesis might be substituted for the participation hypothesis so prominant in human relations theory.

"To bring about change in the behavior of an organization and to get effective acceptance of a new practice, it is necessary to modify the structure of attributes by which the decision makers discriminate among behavioral alternatives."

This statement focuses attention on that part of the current practice where change is absolutely necessary to accomplish "effective acceptance of a new practice." It also suggests that all procedures which will accomplish this effect will be effective change inducers. This result broadens considerably the range of methods which might be used for this purpose. For example modifications might be made in this organization to bring new criteria to bear on behavior selection. As we saw in the case of the effect of data processing personnel on the implementation of recommendations continuously ignored for several years, these kinds of effects can be quite powerful.

XI. SOME DIRECTIONS FOR FUTURE RESEARCH

We have investigated some aspects of the process by which people allocate their limited capacity for problem solving to a complex environment and have suggested a theory of the structure of this process. We have shown that, in an experimental situation at least, parameters can be fitted to this structure which will describe individual behavior. We have also shown that those processes which subjects specify when asked to delegate their decision making to a formal rule all fit this structure. We have, however, specifically not devised a theory which will predict the parameters of such a structure for an individual. This is clearly the next step required in further investigations of problem solving control processes. We do have some thoughts, however, about the nature of this process and a possible approach to research on it.

As we suggested earlier, in many respects EPAM appears to be the most appropriate theoretical base from which to begin this work. On the surface at least we might see the nonsense syllable learning situation as completely analagous to the bidding situation in which we placed our subjects. In the bidding situation the subjects learned to associate problem solving operators with certain stimuli while in the learning situation they learned similarly explicit responses. Thus by calling a problem solving operator a response we can make the situations and the processes seem identical.

It is interesting to observe, however, that these two situations are not identical in certain fundamental properties. We will first

describe this difference and then what we now see at its implications for EPAM and its successors.

In the nonsense syllable situation the subject faces a very orderly world. Attributes of stimulus response pairs are defined for him (those attributes which differentiate letters in the English alphabet) and a consistent criterion function (correct - incorrect) is defined over all stimulus response pairs. Thus by continuously adding known attributes to a discrimination structure he is guaranteed to rather quickly attain a sufficient power of discrimination to correctly associate responses with stimuli. In addition he can add to his discrimination process local attributes of those stimuli for which his discrimination is incorrect. In this way he can keep the number of attributes, and therefore the size of the discrimination process, relatively small. In other words the situation was such that a structure of ad hoc theory was guaranteed to yield understanding.

In the bidding situation, on the other hand, our subjects faced a much less orderly world. The value of the criterion function associated with a response was a very complex function of attributes of the stimuli--an exponential transformation of the output of a random number generator. In addition the set of stimuli from which this function of the response could be calcualted was neither specified nor guaranteed to be stationary over time. Thus it would be difficult to imagine that on any trial our subjects could feel their response was "correct." If they won they wondered how much larger a bid would have also won. If they lost they wondered how much smaller a bid might have won. If we were to place an EPAM model in this situation therefore

we might expect that it would add attributes of the stimulus-response pair on each trial in what an attempt to construct a theory of the situation in which it found itself. We know, however, that it would not succeed and would predict, therefore, that over the course of a hundred trials or so it would have constructed a vast network of ad hoc associations.

We have two reasons for suspecting our subjects did not build such large networks. First, they reported from time to time during the course of their play that they were rejecting one theory (i.e., destroying the network) and starting to work on another. And second, the networks which they specified after many trials were comparatively simple ones i. e., far fewer attributes than trials. We suspect EPAM will require modification to yield this kind of behavior. Besides a source of ad hoc theories which it now receives from a given list (description list), it will need some criterion for testing and rejecting its own structures to stay within some perhaps physiological or real time constraint on net size--or (perhaps and) it will require some process whereby the attributes of feedback which trigger network modifications get changed to limit this process.

For example a criterion based on a function of a sample of trial outcomes (wins and losses) could vastly reduce the size of a network necessary to yield satisfactory discrimination.[55/] Thus

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55/ It is interesting to note that modifications of this latter type is what is implied by most management science models of decision processes.

while EPAM appears to have the basic structural properties required for a theory of problem solving control, it appears that additional mechanisms will be required to permit its effective performance in situations where more complex theories are required.

Utility Theory:

Several attempts have been made to effect a reconciliation between "aspiration level type" theories of behavior and classical utility theory. Great ingenuity has been demonstrated in the formulation of continuous and discontinuous utility functions which under utility maximization assumptions predict the "satisficing" behavior discussed in work on aspiration level theories. By examining the associative structure we have proposed we anticipate two general types of problems associated with these attempts.

First, if the theory we have proposed is correct, a person's apparent utility for particular behavioral alternatives will depend strongly on a number of attributes which in any realistic situation will vary over time. Thus we would predict that out of a relatively stable associative structure for problem solving control will come behavior which would imply great instability in a utility function which does not include consideration of these variables. Since most theories which use utility maximization as their predictive method assume reasonably stable utility functions over time, we find ourselves less than optomistic about their ability to describe individual human behavior.

The second problem we see for the utility theory approach is

that if the utility function is specified to include consideration of those values in the environment which affect it, then utility functions will rapidly approach structures like we have proposed and the criterion of maximization will no longer be required.

If therefore, utility functions are based on outcomes, we predict they will lack the necessary stability for detailed description while, if they include consideration of other variables prior to choice, they will lose their teleological form.

These comments, it should be emphasized, apply primarily to detailed descriptions. As we saw earlier in the case of factory performance certain aggregate functions of individual and organizational behaviors (like averages of their effects) do seem to be consistent with relatively stable cost structures.

Aspiration Level Goal Processes

By studying the behavior of individuals in simple environments, we have shown that a stable association process can be substituted for a dynamic process which has been hypothesized from the study of individual behavior with respect to single variables in a complex environment. From the point of view of understanding the nature of the process which underlies problem solving control we might look on this this as progress--from the point of view of constructing simulation models of certain variables controlled by human decision makers, however, we might regret this result. Our theory suggests that problem solving control process may depend on a wide variety of attributes of the

decision makers' environment besides the variable which may be of interest to a particular investigation of some aspect of his behavior. Thus our theory suggests that for detailed description we will require models to include all the variables which enter into the problem solving control process.

We believe that one direction for fruitful research will be the attempt to discover simple mechanisms which will capture the important aspects of problem solving control without requiring all the detail necessary for a more precise description. Several such mechanisms suggest themselves.

One mechanism would be a simple periodic rule which would assume that problem solving will be allocated to each variable in the environment for a certain period of time with a constant frequency. This wouldcapture the on-off characteristic of problem solving but would miss entirely the perhaps critical detail of exactly when the switching takes place.

Another mechanism which would be only slightly more complicated, is one which includes consideration of performance on the variable of interest in determining the probability of focussing attention on it. As performance declines the probability of problem solving would be increased and vice versa. The effectiveness of the problem solving operator could also be simulated by a random process. In this mechanism we would substitute chance for the effect of all other variables whose effects we anticipate but don't choose to explain.

Obviously such mechanisms can be elaborated as the simulation includes more relevant variables until we approach an environment as complex as that perceived by the decision maker in question. The performance of mechanisms based on less than complete information will have to be judged by those criteria used to evaluate the simulation.

These mechanisms based on the theory of problem solving control which we have proposed differ from some current models of the phenomenon in that they emphasize the on-off characteristics of problem solving operators rather than treating changes in performance as a continuous function of the rate of problem solving. An investigation of the effect of these mechanisms on simulations which include such processes would seem to be straightforward.

APPENDIX A

Instructions for Experimental Situation I

Instructions

The experiment in which you are about to participate is a part of a research project designed to investigate certain fundamental processes of human decision making. During the course of this experiment you have the opportunity to make a number of decisions. These decisions will, by a process described below, determine a measure of your performance in the experiment. This measure will be expressed in dollars and cents and you can think of these as your earnings in the experiment although no payoff will be made. You should attempt to make your decisions in such a way as to make your earnings as large as possible.

On the forms provided you can see that the experiment consists of a number of trials and a decision by you on each trial. Your decision will consist of choosing a number to write opposite each trial number. The numbers you choose can be thought of as dollars and cents, can be positive or negative, and can be of any size you choose. There is absolutely no limit on the number you choose on each trial except that it be in the dollar and cent format.

After you have chosen a number for a trial I will compare that number with the number corresponding to that trial on a long list (5,000 numbers) which I have prepared. Note that the number on my list changes at each trial whether yours does or not. If, when I compare your number with mine on any trial, I find my number is higher than yours, I will say "you win". In this event you will circle your number and note beside it the cumulative number of wins up to that trial. You can think of yourself as winning the money implied by these circled numbers.

If, on the other hand, the number on my list corresponding to the trial is smaller than the number you have written on your list, I will say "you lose" and you can proceed to the next trial.

You will continue to play until you have won 50 times. The number of trials this will take will vary depending on how frequently you win. The minimum number of trials, of course, is 50 but there is no rule as to the maximum number. You may take as many trials as you like or find necessary to win 50 times. Do not feel constrained one way or the other by the fact that the prepared form has 100 trials on it. You may use more or less trials if you like.

In order to limit the number of trials you may find it desirable to play, however, a fee is imposed which you must pay per trial whether you win or lose. Since the fee will vary from experiment to experiment, you will be told the size of the fee per trial before you begin to play.

For example, suppose you played as follows and the trial fee were $.10 per trial.

Trial Number	Decision	Experiment or Response
1	.75	Lose
2	.60	Lose
3	.50	Lose
4	.50	Win

Your earnings through trial 4 would be:

.50 = Sum of circled values
-.40 = Four trials at $.10 per trial
.10 = Earnings through trial 4

Are there any questions about procedure?

Now just a word about the numbers on my list. These numbers were selected carefully but then arranged in a random sequence such that any number can follow any number as one goes down the list. You will be given no information about the set of numbers from which this list was selected.

Since this experiment is designed to reveal certain aspects of your decision process, it would be helpful if you can describe the process by which you select the numbers you write on your list as you go along. If you forget to do this, you may be reminded by the experimenter.

Since most subjects will, like yourself, come from within the school, you are requested not to discuss your experience here outside this room because prior knowledge would, no doubt, influence future subjects and nullify their value to this study.

APPENDIX B

Sample Data Sheets -- Experimental Situation I

Name Subject # 1 DATE 10/4

Trial No.	Position	Trial No.	Position	Trial No.	Position	Trial No.	Position
1	2.00	14	1.75	51	3.00	76	2.50
2	1.50	15	2.50	52	2.50	77	2.00
3	2.00	16	2.50	53	3.00	78	2.00
4	1.50		3.00	54	2.50	79	2.00
5	1.50	17	2.00	55	2.00	30	1.50
6	1.00		2.25	56	3.00	31	2.00
7	1.00		2.00	57	2.00	32	2.00
8	1.50	18	2.00	58	2.00	33	2.00
9	1.00		2.50	59	2.00	34	2.50
10	1.00	3	2.00	60	2.50	35	2.00
11	1.00	4	2.00	61	2.50	36	2.00
12	1.25	5	2.25	62	2.50	37	2.50
13	1.50		2.00	63	3.00	38	2.50
14	1.00	6	2.00	64	2.50	39	3.00
15	1.50	7	1.75	65	2.50	40	3.00
16	1.50	8	1.50	66	2.00	41	2.50
17	2.00	9	2.00	67	1.50	42	2.00
18	2.50		2.00	68	2.50	43	3.00
19	2.00	10	2.50	69	2.00	44	2.00
20	2.00		2.00	70	2.00	45	2.25
21	1.50	11	1.75	71	2.00	46	2.00
22	1.75		2.50	72	1.50	47	2.00
23	1.75	12	2.50	73	2.00	48	2.00
24	2.00	13	2.00	74	2.25	49	2.00
25	2.00		2.00	75	2.25	50	2.50

Subject # 1 ____ 10/9

1	2.50				51		76		
2	2.00	47			52		77		
3	3.00				53		78		
4	2.50				54		79		
5	2.00				55		80		
6	2.00				56		81		
7	2.00				57		82		
8	2.00				58		83		
9	2.00				59		84		
10	2.00	48			60		85		
11	2.50	49			61		86		
12	3.00				62		87		
13	2.50				63		88		
14	2.00	50			64		89		
15					65		90		
16					66		91		
17					67		92		
18					68		93		
19					69		94		
20					70		95		
21					71		96		
22					72		97		
23					73		98		
24					74		99		
25					75		100		

DATA SHEET

NAME Subject # 2 DATE 8/21/62

Trial No.	Decision		Trial No.	Decision		Trial No.	Decision		Trial No.	Decision
1	1.00	1.	26	1.70	18	51	2.10		76	
2	.90	2.	27	1.80	19	52	2.10	31	77	
3	.85		28	1.90	20	53	2.15	32	78	
4	.10	3.	29	2.00		54	2.20		79	
5	.90	4.	30	2.00	21.	55	2.15	33	80	
6	1.00		31	2.20		56	2.15		81	
7	.90	5.	32	2.20		57	2.15		82	
8	.95	6.	33	2.00	22	58	2.10		83	
9	1.00		34	2.10	23	59	2.10	34	84	
10	1.00	7.	35	2.15		60	2.10	35	85	
	1.20	8.	36	2.10	24	61	2.10	36	86	
	1.30	9.	37	2.20		62	2.10	37	87	
	1.50		38	2.00		63	2.20		88	
	1.40	10.	39	1.90		64	2.10		89	
✓	1.40	11.	40	1.90		65	2.10	38	90	
	1.45	12.	41	1.80	25	66	2.10	39	91	
	1.50	13.	42	1.90	26	67	2.00	39	92	
	1.50		43	2.00	27	68	2.10		93	
	1.30	14.	44	2.10		69	2.10		94	
	1.35		45	2.00		70	2.00		95	
	1.35	15.	46	2.00	28	71	2.10		96	
	1.50		47	2.10	29	72	2.00	40		
	1.50	16	48	2.20		73				
	1.60	17	49	2.10		74				
	1.70		50	2.10	30	75			10	

DATA SHEET

NAME Subject # 3 DATE 3/17/52

Trial No.	Decision	Trial No.	Decision	Trial No.	Decision	Trial No.	Decision
1	[illegible]	26	17 (1.05)	51	1.62	76 47	(1.70)
2	[illegible] L	27	19 1.15	52 53	(1.75)	77	2.00
3	2.00 L	28	20 [illegible]	53 54	(1.60)	78	1.95
4 1	(1.00) W	29	1.25	54 55	[illegible]	79	1.90
5	1.50 L	30	21 1.20	55 56	(1.60)	80 48	(1.75)
6	1.00 L	31	1.20	56 57	(1.70)	81	1.80
7 2	(2.50)	32	1.20	57 58	(1.75)	82	1.75
8 3	(1.50)	33	22 (1.25)	58	2.00	83 49	(1.65)
9	0.75 L	34	23 (1.50)	59 60	(1.75)	84	1.65
10 4	0.80 W	35	24 (1.30)	60 40	(2.00)	85 50	(1.50)
5	(0.80) W	36	25 (1.25)	61 41	2.10	86	
6	(0.70)	37	(1.40)	62	(2.00)	87	
7	0.70	38	1.60	63	2.50	88	
8	(.72)	39	26 (1.50)	64	2.30	89	
9	(0.72)	40	1.55	65 42	(2.00)	90	
10	(.75)	41	27 (1.50)	66	2.25	91	
11	(0.75)	42	28 (1.55)	67 43	(2.20)	92	
12	(.75)	43	29 (1.50)	68	2.22	93	
13	(.80)	44	1.45	69	2.20	94	
14	(.82)	45	1.45	70	2.10	95	
15	(.90)	46	30 (1.50)	71	2.00	96	
	1.00	47	31 (1.65)	72 44	(1.70)		
16	(.95)	48	1.90	73 45	(1.80)		
17	(1.00)	49	1.45	74	2.00		
	1.10	50	32 (1.70)	75 46	(1.90)	100	

DATA SHEET

NAME Subject # 4 DATE 17 Aug 62

Trial No.	Decision	Trial No.	Decision	Trial No.	Decision	Trial No.	Decision
1	.20	1 26	2.00	24 51	- 3.00	76	3.10
2	.20	2 27	2.00	25 52	- 3.10	77	3.10
3	.20	3 28	2.00	26 53	- 3.00	78	3.10
4	.25	4 29	- 3.00	54	- 3.20	79	3.10
5	.25	5 30	- 3.00	55	- 3.00 33	80	3.10
6	.25	6 31	- 3.00	56	3.50	81	3.10
7	.30	7 32	- 3.00	57	3.50	82	3.10
8	.30	8 33	2.50 -	58	3.50	83	3.10
9	.30	9 34	2.50 -	59	3.50	84	- 3.00
10	.35	10 35	2.50 -	60	3.50	85	- 3.00
11	.35	11 36	2.50 -27	61	3.50	86	- 3.00
12	.40	12 37	2.50 -	62	3.50	87	- 3.00
13	.40	13 38	2.50 -	63	3.50	88	- 3.00
14	.50	14 39	2.50 -	64	3.50	89	- 3.00
15	.60	15 40	2.50 -	65	3.50	90	- 3.00 34
16	.70	16 41	2.50 -28	66	- 3.00	91	- 3.00
17	.80	17 42	2.50 -	67	- 3.00	92	
18	.90	18 43	2.50 -29	68	- 3.00	93	
19	1.00	19 44	2.50 -	69	- 3.00	94	
20	1.20	20 45	2.50 -	70	- 3.00	95	
21	1.50	21 46	2.50 -30	71	- 3.00	96	3.50 3
22	1.50	21 47	3.00 31	72	- 3.00 34		
23	1.50	22 48	- 3.00	73	- 3.00		
24	1.50	23 49	- 3.00	74	- 3.00		
25	1.50	23 50	- 3.00 32	75	- 3.00 35	10	

5
6
25
1
2
15
1
12
16
27
16

APPENDIX C

Instructions for Experimental Situation II

Part I

Part II

Part III

INSTRUCTIONS

Experimental Situation II

Part I

You are about to participate in a series of three experiments designed to yield data on certain fundamental aspects of human decision making. By a process described below you can earn as much as $3.00 during these experiments. Since most subjects will, like yourself, come from within the school, you are requested not to discuss your experience here outside this room because prior knowledge would, no doubt, influence future subjects and nullify their value to this study.

In the first experiment imagine that you are engaged in determining a series of fixed price bids in a market where the lowest bid automatically wins the contract. On those bids where you win the contract you will earn a fixed percentage of your bid price as your profit. Your earnings during the first experiment will be the sum of the profits you have earned on the contracts you have won.

Throughout this experiment you will be bidding on relatively similar contracts for which the low bid from all other bidders has been selected and listed on a form visible only to the experimenter. Thus if your bid is below the bid on the list for that contract you will automatically win the contract. If your bid is higher than the bid on the list, you will win neither the contract nor the profit associated with it. You will learn whether or not you have won the contract after each bid. Variations in bids on the prepared list are like those you might find in any real market.

The first experiment will consist of 75 bids. On the form provided, please circle those bids on which you win the contract. In order to indicate the order of magnitude into which the bids have been scaled you are requested to make your first bid $1.00.

If you have no questions, we can begin.

Part II

In this part of the experiment the rules are essentially the same as they were for Part I. The difference is that you will now place bids simultaneously in two different markets. The experimenter has two lists before him which consist of the low bids from all other bidders in these markets. You will be paid the same fixed percentage of the bid price on all those contracts you win that you were paid in Part I.

Following your bids in both markets you will be told which contracts you have won before you must bid again. On the form provided please circle those bids on which you win the contract.

There is one limitation on your bidding in this experiment. You will be permitted to change your bid in only one market at a time. Your bid in the other market must remain the same. In each pair of bids you are free to choose the bid you wish to change.

This part of the experiment will consist of 50 pairs of bids. In order to indicate the order of magnitude into which the bids in this experiment have been scaled you are requested to make your first bid in each market $1.00.

If there are no questions, we can begin.

Part III

In this part of the experiment the rules are essentially the same as they were in Part II. The difference is that you will now place bids simultaneously in three markets instead of two. The experimenter has three lists before him which consist of low bids from all other bidders in these markets. You will be paid the same fixed percentage of the bid price on those contracts you win that you were paid in Parts I and II.

Following your bids in the three markets you will be told which contracts you have won before you bid again. On the form provided, please circle those bids on which you win the contract.

The same limitation is imposed on your bidding in this part of the experiment as was imposed in Part II, i.e., on each trial you are permitted to change your bid price in only one of the three markets. Your bid in the other two markets must remain the same. On each trial you are free to choose the bid you wish to change.

This part of the experiment will consist of 50 trials of three bids each. In order to indicate the order of magnitude into which the bids in the experiment have been scaled you are requested to make your first bid in each market $1.00.

If there are no questions, we can begin.

APPENDIX D

Sample Data Sheets -- Experimental Situation II

Subject # M

3.	2
(2.5)	(1.75)
2.6	(1.8)
(2.55)	(1.9)
(2.58)	2.2
2.6	(2.1)
(2.57)	2.15
(2.58)	(2.12)
2.6	2.12
2.59	2.1
2.57	(2.05)
2.5	2.07
2.45	2.05
(2.2)	(2)
2.3	2.02
(2.25)	2.01
2.26	#1.8
2.24	(1.5)
(2.15)	(1.6)
2.2	1.75
(2.18)	1.65
2.2	(1.5)
2.19	1.7
2.17	(1.6)
2.13	(1.7)
(L) 16	L=13

W = 21
L = 29

%W = 42%

PART II

DATA SHEET

Subject # M

DATE

	L		R		L		R
1	1.0	26	1.0	51	3.3	76	1.6
2	1.5	27	1.0	52	3.4	77	1.6
3	1.5	28	1.3	53	3.4	78	1.65
4	1.5	29	1.2	54	3.6	79	1.65
5	1.6	30	1.2	55	3.6	80	1.55
6	1.6	31	1.1	56	3.7	81	1.53
7	1.7	32	1.1	57	3.7	82	1.45
8	1.75	33	1.0	58	3.7	83	1.5
9	1.75	34	1.2	59	3.75	84	1.5
10	1.85	35	1.2	60	3.75	85	1.45
11	1.85	36	1.25	61	3.75	86	1.5
12	1.9	37	1.25	62	3.8	87	1.5
13	1.9	38	1.2	63	3.8	88	1.55
14	2.0	39	1.2	64	3.85	89	1.6
15	2.2	40	1.2	65	3.9	90	1.6
16	3.0	41	1.2	66	3.9	91	1.65
17	3.0	42	1.5	67	3.9	92	1.5
18	4.0	43	1.5	68	4.0	93	1.55
19	5.0	44	1.5	69	4.0	94	1.6
20	4.5	45	1.5	70	4.3	95	1.6
21	X 4.0	46	1.5	71	4.2	96	1.6
22	3.5	47	1.5	72	4.2	97	1.7
23	3.5	48	1.6	73	4.2	98	1.6
24	3.5	49	1.7	74	4.1	99	1.65
25	3.3	50	1.7	75	4.	100	1.6

L=4 L=9 L=4 L=8

PART II

DATA SHEET

Subject # M

DATE

Trial No.	L Duration	L Position	R Duration	R Position	Trial No.	Duration	Total Ms.	Position
1	4.0		(1.5)		51		76	
2	(3.9)	27	(1.5)		52		77	
3	(3.5)	28	1.55		53		78	
4	3.9	29	1.55		54		79	
5	(3.9)	30	1.5		55		80	
6	(3.9)	31	(1.48)		56		81	
7	(4.0)	32	(1.48)		57		82	
8	(4.2)	33	1.48		58		83	
9	(4.2)	34	(1.45)		59		84	
10	(4.2)	35	(1.48)		60		85	
11	4.3	36	(1.48)		61		86	
12	(4.25)	37	1.48 (1.5)		62		87	
13	(4.25)	38	(1.46)		63		88	
14	4.25	39	(1.48)		64		89	
15	4.2	40	1.48		65		90	
16	4.0	41	(1.48)		66		91	
17	(4.0)	42	1.5		67		92	
18	(4.0)	43	(1.47)		68		93	
19	4.1	44	1.47		69		94	
20	(4.0)	45	(1.47)		70		95	
21	4.0	46	(1.48)		71		96	
22	4.0	47	1.5		72		97	
23	(3.8)	48	(1.5)		73		98	
24	(3.8)	49	1.55		74		99	
25	(4.0)	50	(1.55)		75		100	

L = 9 R = 10

L = 17/75 = 23%

W = 77% L 44/150 = 29

L 27/75 = 36%

W = 64

PART III

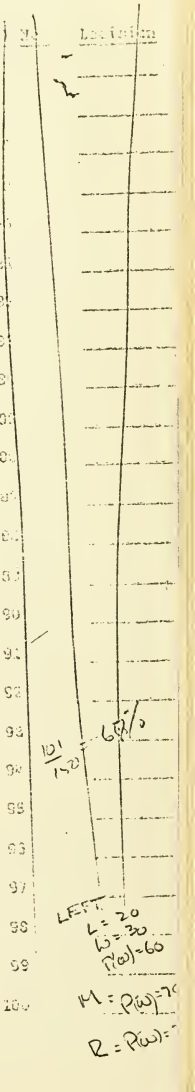
DATA SHEET

Subject # M

DATE

Trial No.	L	Trial No.	M	Trial No.	R	Trial No.	Location
1	(1.5)	26	(1.5)	51	1.5	76	
2	(1.7)	27	(1.5)	52	1.5	77	
3	(1.7)	28	(1.5)	53	(1.7)	78	
4	(2.0) (1.7)	29	(2.0)	54	(1.2)	79	
5	2.0 1.7	30	(3.0)	55	(1.2)	80	
6	(1.7)	31	(3.)	56	(1.5)	81	
7	(1.8)	32	(3.)	57	(1.5)	82	
8	(1.8)	33	(3.5)	58	(1.5)	83	
9	1.8	34	(3.5)	59	(2.0)	84	
10	(1.5)	35	(3.7)	60	2.0	85	
11	2.	36	(3.7)	61	2.0	86	
12	1.8	37	(3.7)	62	2.0	87	
13	(1.8)	38	(4.)	63	(2.0)	88	
14	(1.8)	39	(4.5)	64	(2.)	89	
15	2.2	40	(4.5)	65	(2.)	90	
16	2.	41	(4.5)	66	(2.)	91	
17	2.	42	(6)	67	(2.)	92	
18	2.	43	6	68	2.5	93	
19	1.8	44	(6)	69	(2.5)	94	
20	(1.6)	45	(6)	70	(2.5)	95	
21	1.6	46	6	71	2.6	96	
22	(1.6)	47	6	72	2.45 (2.35)	97	
23	(1.6)	48	5.5	73	2.45	98	
24	(1.6)	49	5.5 (5)	74	(2.35)	99	
25	(1.6)	50	(5)	75	(2.35)	100	

L=10 M=5 R=9



PART III

Subject # M

	L	M	R
1	1.7	5	2.35
2	1.65	5	2.35
3	1.6	5	2.35
4	1.6	5	2.5
5	1.6	5.5	2.5
6	1.6	5.5	2.6
7	1.7	5.5	2.6
8	1.7	5	2.6
9	1.7	5	2.7
10	1.8	5	2.7
11	1.65	5	2.7
12	1.65	5	2.8
13	1.65	5.5	2.8
14	1.65	5.5	3
15	1.75	5.5	3
16	1.75	5.7	3
17	1.75	5.8	3.3
18	1.75	5.7	3.2
19	1.8	5.7	3.2
20	1.8	5.8	3.2
21	2	5.8	3.2
22	2	5.8	3.5
23	1.8	5.8	3.5
24	1.8	5.8	3.6
25	1.8	5.5	3.6

L=10 M=10 R=5

APPENDIX E

Samples of Rules Written by Subjects in Experimental Situation III

Subject A:

Rule for one-market situation:

"Make first bid $1.00. Now follow this rule: When you lose a bid drop the bid $.03 on successive bids until you win. When you win a bid, first repeat the bid and after the second accepted (win) bid raise the bid $.03 for each successive win."

Rule for two-market situation:

"When both bids lose reduce the left market by $.05. When one bid loses reduce the losing bid $.05. When both bids win raise the bid which has been constant for the greatest number of trials $.05.

Exception:

1. If the same bid wins twice in a row, and the other bid loses twice in a row, raise the winning bid $.05 and leave the losing bid alone."

Subject B:

Rule for one-market situation:

"When win, increment by $.10 and play 4 trials. If on 4th trial after + $.10 increment, still winning; increment by $.10 again. Whenever lose decrease by $.05 until get a win, at which you will play 4 trials, etc."

Rule for two-market situation:

"Loss rule: ~ $.11

Win rule: + $.05

If a loss: (one or more)

1. Always invoke loss rule first.
2. Always operate loss rule on higher number.
3. If #2 ambiguous, operate loss rule on historically higher average value.
4. If #3 ambiguous use loss rule in left market.

If two wins:

1. Use win rule on higher number.
2. Use win rule on higher average value
3. Use win rule on left market first."

Subject C:

Rule for one-market situation:

"If we win 3 times in a row, increase bid by $.10. If we lose two times in a row, decrease bid by $.15 and repeat two rules. Do not change any bid until you have 3 wins or 2 losses in a row."

Rule for two-market situation:

"Trial 1. Bid $1.00 in each market.

Trial 2. If one win, decrease loser by $.20.
If two wins increase right by $.10.
If two losses decrease right by $.20.

Trial 3. If one win, decrease loser by $.20.
If two wins, increase lowest bid by $.10.
If two losses, decrease highest bid by $.20.
If two bids are the same in any bid and either 2 losses or 2 wins, change right bid.
Do not go above $1.50 or below $.70.
Follow rule for trial 3 on remainder of trials."

Subject D:

Rule for one-market situation:

"Start bidding at $1.05.
Evaluate performance after every 6 plays.
If winning less than 4 out of 6, lower bid $.05.
If winning 4, continue to bid same figure.
If winning 5 or better increase by $.05.
In all cases bid same figure for 6 successive plays."

Rule for two-market situation:

"Play left at $1.75, right at $1.50.
In all cases make same play for six successive times.
If both winning 4 out of 6 maintain same play (bid).
If one (market) winning 5 or more and the other 4
raise former by $.25, keep latter the same.
If one (market) winning less than 4, other 4,
lower former by $.25, keep latter the same.
If both winning 5 or more raise bid on left by $.25.
If both winning less than 4 lower right by $.25.
If one winning 5 or more and the other winning less
than 4, raise former by $.25, keep latter the same."

Subject E:

Rule for one-market situation:

"Start at $1.00. If you win go up $.10. If you lose, go down $.10. If you get 3 wins or losses in a row, then change your increment to $.20. If you win or lose twice in a row at $.20, then go back to $.10 increments."

Rule for two-market situation:

"The starting point is $1.00 again.
The primary attention is paid to the losing market. Leave winning market to adjust itself.
If you win on both markets at the start pick left market and increase it $.10.
If you win on both increase the bidding by $.10 in the winning market that you picked.
When you lose in a market decrease the bid by $.20 at first to avoid losses and on the next trial increase the market that seems to be on a winning streak by $.10.
Keep this pattern."

Subject F:

Rule for one-market situation:

"Start at $1.00. If you win raise bid by $.05 but stay the same if the next highest bid has been tried 3 or more times and has always lost. If you win 3 times at this max. bid then you raise $.05 on each additional consecutive win. If you lose, decrease the bid $.10 but not lower than $.10 less than the amount that has won the greatest number of times previously (use $1.00 on first 5 trials)(if two numbers have won the same number of times previously, use the lower number)."

Rule for two-market situation:

"Start at $1.00 each, if both win, add $.05 to left. After that, if both win, add $.05 to the lower of the two, or if they are equal, to the one that has had the highest number of previous wins. (If both have had the same number, add to the one with the highest previous winning bid. If this is the same, choose the left arbitrarily).

If one wins, and one loses add $.05 to the winning bid, but stay the same if the next highest bid has been tried twice or more, and lost each time. (This applies to two wins also).

If both lose, subtract $.05 from the lower, or if equal, the one with most losses or if that is equal, the one with the lower maximum winning bid."

Subject G:

Rule for one-market situation:

"Start with bid of $1.50.
Stay with this bid until you lose 2 bids in a row, then drop to $1.25. The first time you next win, raise the bid back to $1.50 and stay there until you lose twice in a row again."

Rule for two-market situation:

"Start both markets at $1.50.
If both win, keep the bids fixed at $1.50.
If both lose, drop the left to $1.25. Proceed in this manner until both win again, then raise the left bid back to $1.50. If only one bid loses, lower that bid to $1.25 until both win again, then raise that bid back up to $1.50."

Subject H:

Rule for one-market situation:

"When I lose I will drop by one ($.01) - then if I win I will keep it constant for the next two and will raise it by one if I win both."

Rule for two-market situation:

"Starting at $1.00 I will raise by one in either market. If I lose in one market I will hold that market constant and raise the other. If both win go up in lowest market. If both lose, hold both constant."

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